COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

October 1954

Photograph by Tom Walters

Boiler room at Sevier, N. C., plant of American Thread Co. See page 46.

Corrosion Control in Steam Power Plants

Interpreting Graphitization for Power Engineers

Forced Outage Rates of Turbines and Boilers

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 26 **No. 4**

October 1954

Feature Articles

Editorials

Departments

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BPA

Printed in U. S. A.

Fly Ash Problem Solved By Central Station

This Pennsylvania utility felt that as long as you can *see* dirty stack discharge, you have a problem. To solve it, they decided to insist on fly ash collection equipment with very high efficiency.

The electrical precipitators they chose, which were placed after existing mechanical collectors, are Cottrells, designed and built by Research Corporation. Their effectiveness is demonstrated in the above unretouched photographs. At the left, the precipitators were turned off long enough to take the picture showing the volume of fly ash discharged by the boilers. At the right, the precipitators are turned back on. Stack discharge is visually clean.

This is another example of industry's trend toward establishing its own higher standards for nuisance abatement. Research Corporation, which has made more fly ash installations than any other company, cites the following comparison:

In the period from 1923 to 1939 only 11% of its power plant customers specified fly ash collection efficiency of 95 to 98%. In recent years, that 11% has risen to fully 90%.

One reason, of course, is the generally increasing emphasis on community relations. Another factor is that far-sighted companies are anticipating stricter smoke regulations. They are anxious to install equipment that will end their smoke problems now and also prevent such problems from occurring in the future.

Still another factor is this. In recent years, with modern coal pulverization and advanced boiler design, there has been an increase in the fineness of fly ash particles. This calls for the most efficient equipment available.

Read—in Bulletins FA and MI—about Cottrell equipment and the Research Corporation's MI Rapper. This device eliminates rapping puffs and enables the precipitator to maintain, continuously, its high collection efficiency. Write for your copies today.

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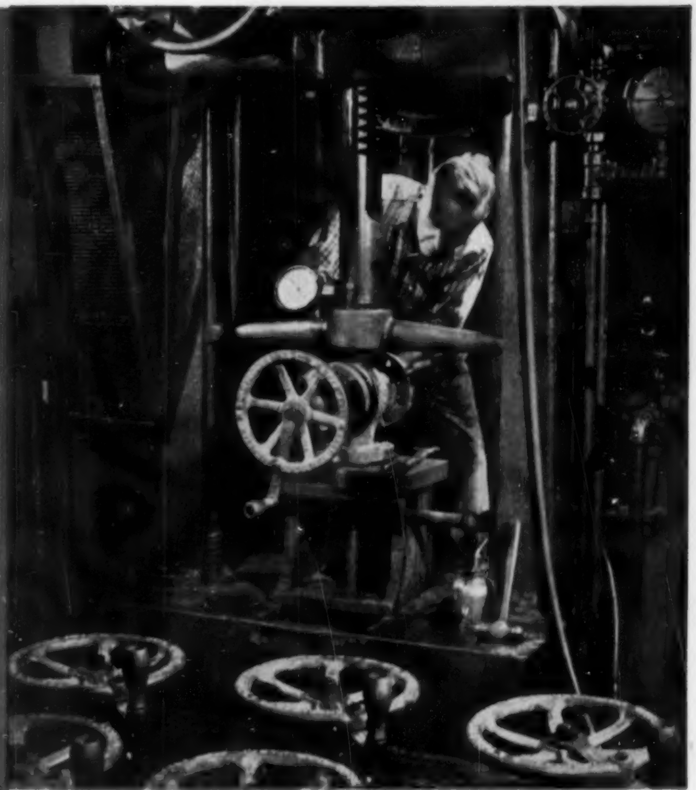

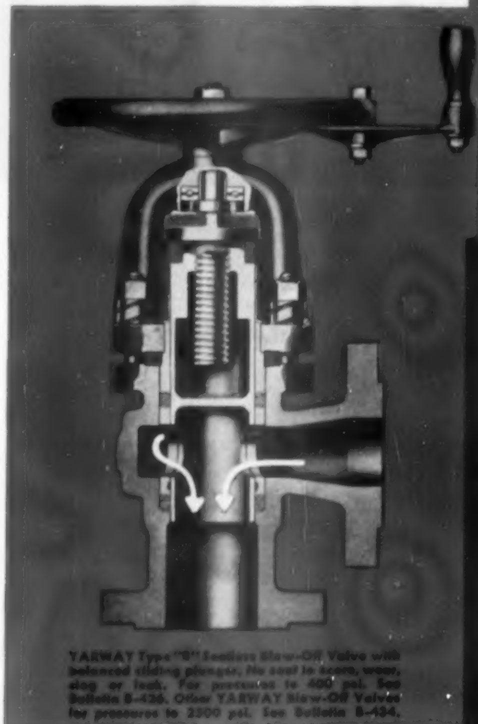

YARWAY Type "B" Seatless Blow-Off Valve with balanced sliding plunger. No seat to score, wear, clog or leak. For pressures to 400 psi. See Bulletin B-426. Other YARWAY Blow-Off Valves for pressures to 2500 psi. See Bulletin B-434.

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WATER COLUMNS AND GAGES
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DIGESTER VALVES
STEAM TRAPS
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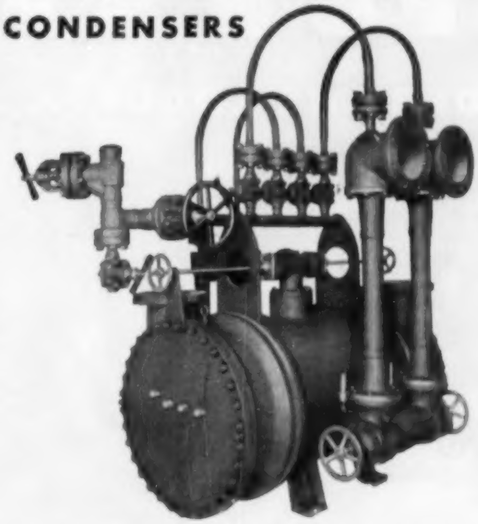
C. H. Wheeler Steam Jet Ejectors are the development of 35 years of pioneering in this field. Known as "Tubejets," these vacuum pumps have no moving parts. Hence, they are simple to operate, require almost no maintenance and last longer. Modern Power plants use single or two-stage Tubejets with surface inter-after condenser for the vacuum requirements of steam condensers. Special arrangements of standard Wheeler ejector assemblies can be provided for any unusual installation or performance requirements. Catalog #1462 gives you detailed descriptions and some useful temperature and pressure conversion tables. Write for it.



SPECIAL TYPE TUBEJET VACUUM PUMP FOR HIGH PRESSURE AND HIGH SUPERHEAT

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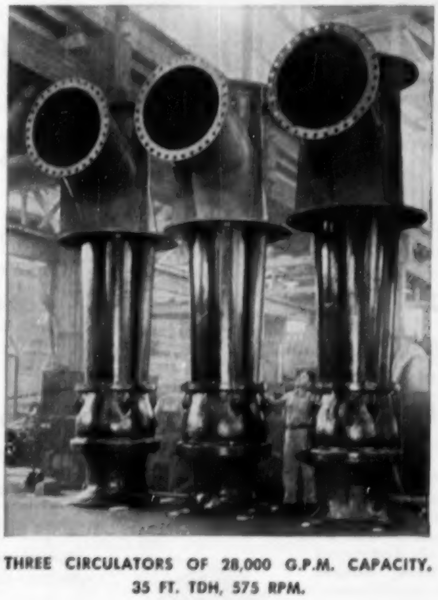
Wheeler-Economy Pumps for Condenser Cooling Water Circulation are made in horizontal double suction and vertical submerged, axial mixed flow types. These pumps are noted for reliability, the result of superior modern design and heavy duty, quality construction. They are built in all sizes to meet capacity requirements up to 200,000 GPM. Wheeler-Economy Circulating Pumps are also furnished in special metals to handle corrosive waters. The impellers are designed for satisfactory operation during all load requirements.

Economy engineers are pioneers in the successful application of axial flow pumps in circulator service. These pumps can be furnished in "pull-out" type with distinctive design features, permitting removal of all operating parts, without dismantling the complete pump or disturbing any pipe connections.

For top performance in power plant duty count on Wheeler-Economy Pumps. Write for catalogs #G-349 and G-1050.



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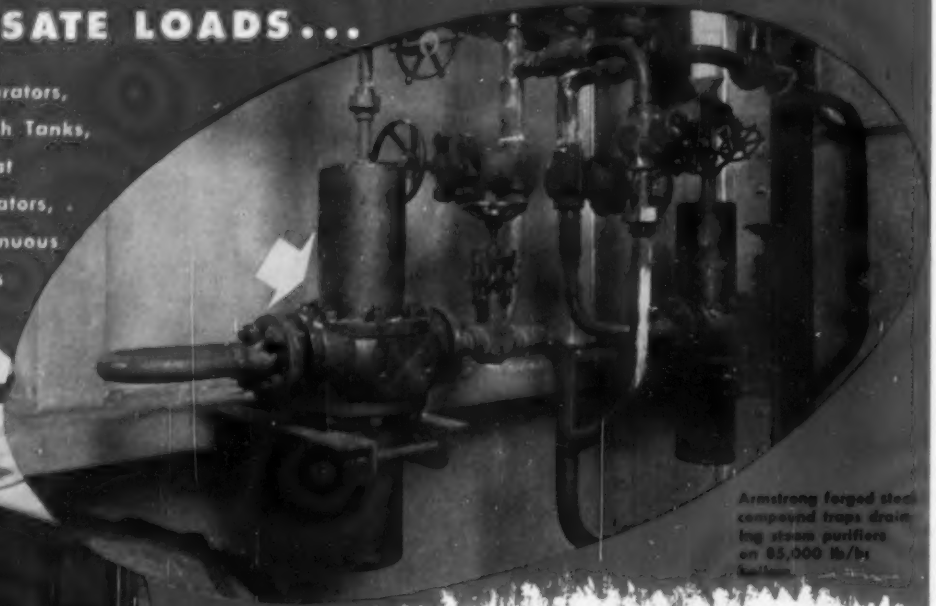

Armstrong forged steel compound traps draining steam purifiers on 85,000 lb/hr boilers.

Armstrong cast semi-steel compound trap draining coils of large storage type hot water heater.

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Because:

1. **They provide automatic drainage of condensate** or boiler carryover loads too big for ordinary traps to handle (up to 300,000 lbs/hr).
2. **They are relatively small size**—the No. 237 compound trap is only twice the height and size of the largest Armstrong standard trap, yet has many times the capacity.
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Your local Armstrong Representative is fully qualified to answer your questions about these traps and their use. Give him a call, or write:

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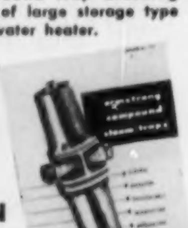
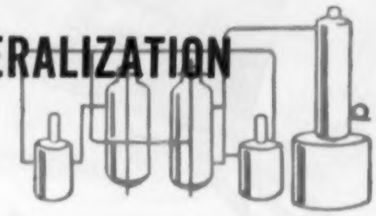


For complete information ask for 8-page bulletin, No. 215 . . . explains and illustrates operation and installation of Armstrong Compound Traps; includes physical data and list prices. Free on request—no obligation.

ARMSTRONG STEAM TRAPS

HIGHER WATER PURITY BY DEMINERALIZATION



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Long experience with *all* phases of water conditioning problems places Cochrane in the position of leader in the design and application of equipment to meet the exacting requirements of demineralization.

Cochrane Demineralizers now operating on boiler feed and process waters are continuously producing effluents with total dissolved solids and silica residuals approaching zero, within the limits of accuracy of available testing methods. These include 2-bed, 3-bed and 4-bed systems—compact mixed bed units—manually controlled or automatically operated.

Cochrane engineers and manufactures every type of ion exchange precipitation type water conditioning equipment—which assures you of unbiased recommendations for equipment best suited to your requirements. Its complete service provides single responsibility for engineering, fabrication and continued satisfactory operation.

For information on Cochrane Demineralizers, write for Publication No. 5800 and reprints on demineralization.

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Virginia Electric and Power Co.
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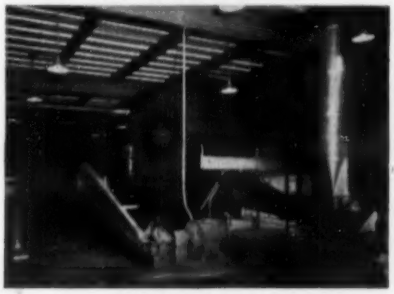
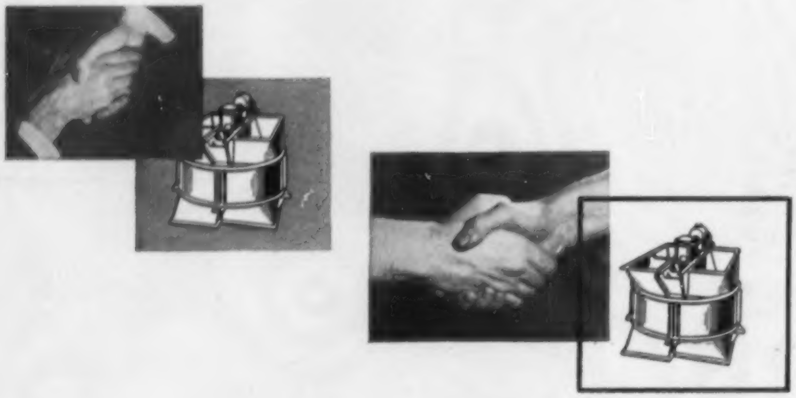


View of Dust Tight Flight Conveyor
Distributing Coal to Bunkers (New Addition)

View of Belt and Belt Driven Tripper
Distributing Coal to Bunkers (Old Building)



How to STOP

VULCAN

Dual-Motor Wall Deslaggers

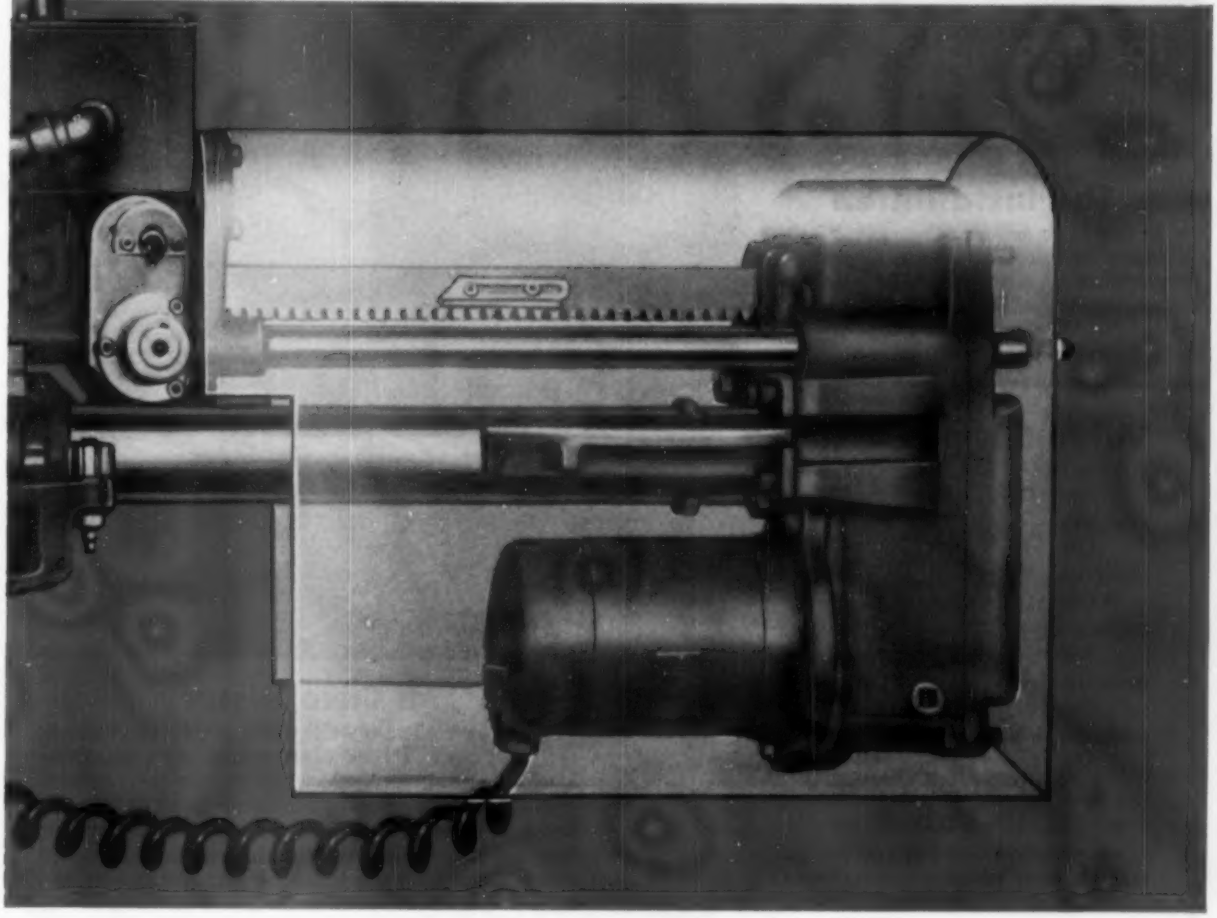
With direct-acting valve Clean BETTER and FASTER

KEEP slag and sintered dust from upsetting heat-transfer capacity and superheat or reheat control. Stop their build-up—quickly and effectively—with the high-power mass blowing and fast action of Vulcan Wall Deslaggers.

Thanks to dual-motor drive—electric or air, electric shown—a Vulcan Deslagger

VULCAN *Automatic*

SLAG BUILD-UP



extends into the boiler, cleans and retracts from the high-temperature zone—all in 76 seconds. The cycle can be repeated often, if needed to control deposits.

Steam, air or water—or any combination of them—may be used as the blowing medium without change in equipment. The blowing or cleaning arc can be any angle up to a full 360 degrees.

The story is told in detail by new Bulletin 1016. Write for it.

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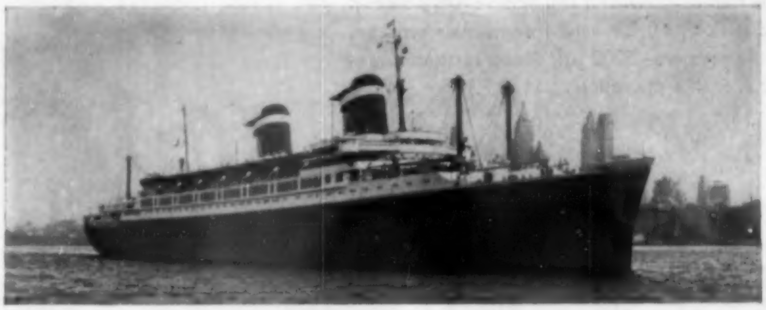
Soot BLOWERS

HALL INDUSTRIAL WATER REPORT

Hall Laboratories, Inc.—A Subsidiary of Hagan Corporation, Pittsburgh, Pa.

Volume 2 | OCTOBER 1954 | Number 5



Stops Scale in Seawater Evaporators

HAGEVAP LP* has been in continuous use in the large modern distillation plant on the S.S. *United States*, maintaining scale-free evaporators and assuring production of the highest quality fresh water, throughout her two years as queen of the North Atlantic passenger service.

These results on the S.S. *United States* confirm similar experience by United States Lines on the S.S. *America*, where HAGEVAP LP was introduced in the spring of 1949. In the intervening five years, the four multiple-effect salt-water evaporators on this liner have required almost no chemical or mechanical cleaning, while continuously and currently producing at better than rated capacity.

The two new luxury passenger liners of American Export Lines, the S.S. *Independence* and S.S. *Constitution*, entered the Mediterranean service in 1950 with HAGEVAP LP specified initially as the evaporator feed treatment. After four years' service, the huge seawater evaporators on these vessels are still free of scale deposits.

HAGEVAP LP feed treatment developed by Hall Laboratories and applied in the marine field by Bull and Roberts, Inc., is now the accepted standard for vacuum-type, single or multiple-effect seawater evaporators, and in most cases is specified by the owners or builders on new construction of passenger, cargo or tank vessels. In recent years, completely automatic feed treating equipment has been perfected, completing the full development of what amounts to push-button control of the problem of scale accumulations in seawater evaporators.

Wall Wrecker Whipped

Three times in two years an eastern Pennsylvania hospital had to tear out a wall in a new domitory building to replace corroded condensate return lines. Leaking lines had also stained ceilings and brickwork in other parts of the building, and the replacement of traps and unit heater coils was a constant expense.

Hall field engineer R. B. Carey recommended treatment of the system with a few ppm of Hagafilm,* which forms a thin film on the metal condensate lines.

In the three years since Hagafilm treatment was instituted, there has been no further failure of the condensate return system in any part of the building. Maintenance and replacement of traps and heater coils has ceased to be a problem.

*Registered Trademark

Hall Engineer to be Guest Speaker

R. K. Scott, head of the Identification Group at Hall Laboratories, will be a guest speaker at the X-Ray Diffraction School of the General Electric Company to be held in Milwaukee from September 27 to October 1. Subjects to be discussed will include the application of X-ray diffraction and fluorescence to chemistry, metallurgy, ceramics and other fields.

Mr. Scott will describe the work done by his group at Hall Laboratories, where X-ray diffraction is one of the means used to tell what substances are present in all sorts of samples of solid material. More than a hundred different constituents have been identified in deposits from boilers and other equipment in systems using water for all sorts of industrial operations.

Pamphlets Available

A series of pamphlets and booklets pointing out the practical importance of various phases of water conditioning has been published by Hall Laboratories.

Four of the pamphlets are now available on request.

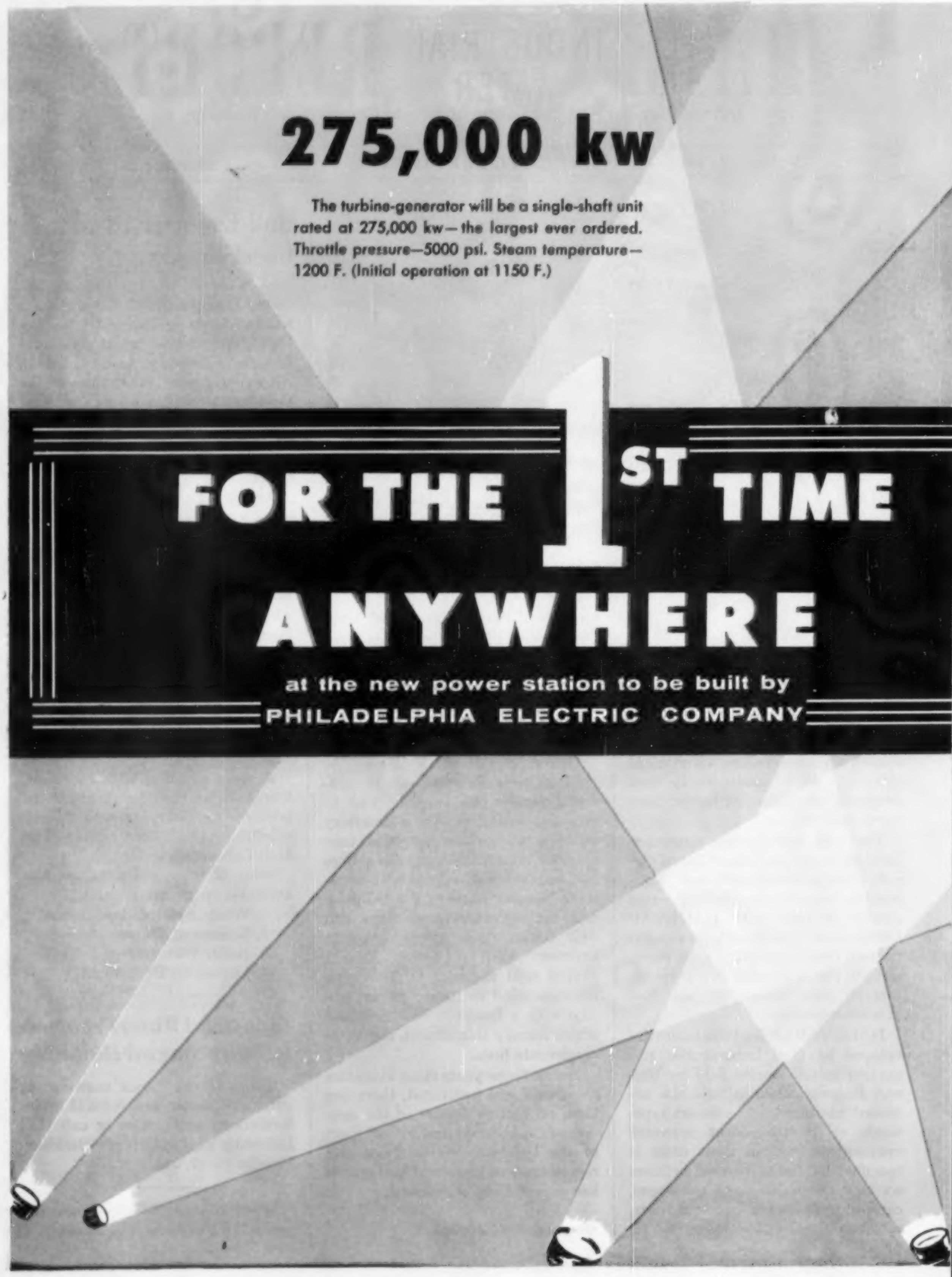
1. What is Hall Laboratories?
2. Sources of Water
3. Boiler Water
4. Laying-up Equipment

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information, write, wire or call Hall Laboratories, Inc., Hagan Building, Pittsburgh 30, Pa.

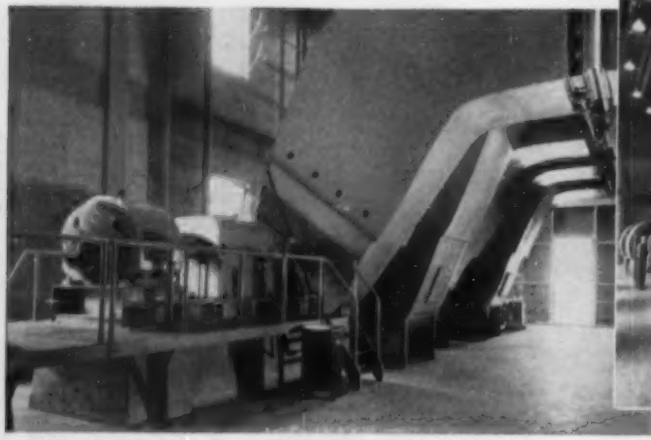
Water is your industry's most important raw material. Use it wisely.

HALL LABORATORIES, INC.—CONSULTANTS ON PROCUREMENT, TREATMENT, USE AND DISPOSAL OF INDUSTRIAL WATER

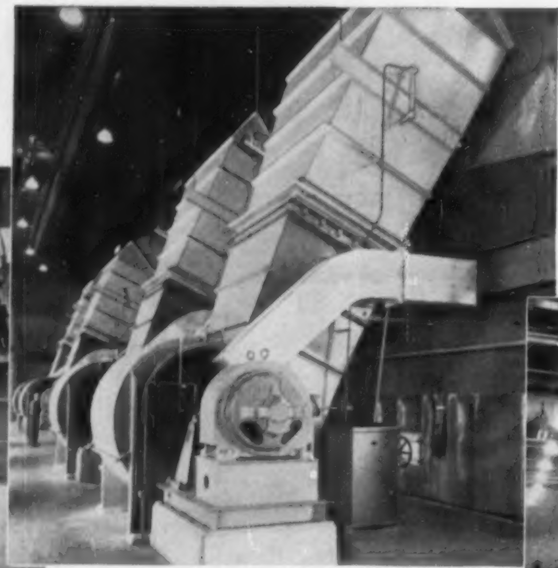


275,000 kw
The turbine-generator will be a single-shaft unit rated at 275,000 kw—the largest ever ordered. Throttle pressure—5000 psi. Steam temperature—1200 F. (Initial operation at 1150 F.)
FOR THE 1ST TIME ANYWHERE
at the new power station to be built by
PHILADELPHIA ELECTRIC COMPANY

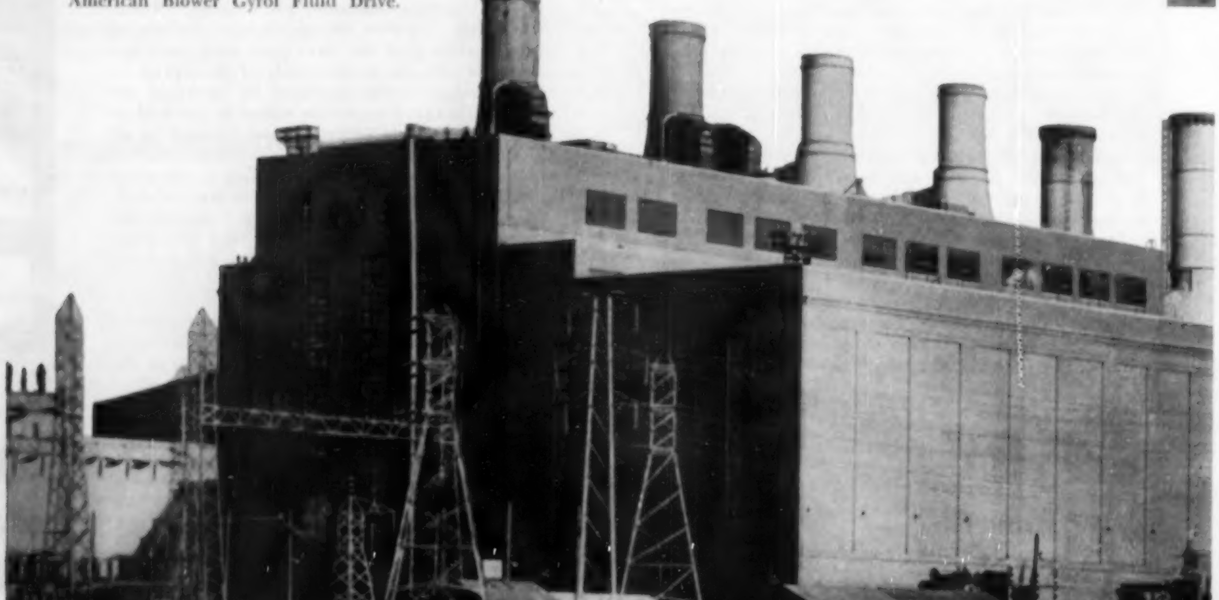
Niagara Mohawk expands



Installed at Niagara Mohawk's Oswego Station are two American Blower Induced Draft Fans, rated 181,000 cfm @ 310°F @ 14.0" SP @ 1150 rpm @ 515 BHP. Each is driven through an American Blower Gÿrol Fluid Drive.



Installed at Dunkirk Station are American Blower secondary air fans with inlet vane control. Rated capacity, 112,000 cfm, 12" wg, 1190 rpm.



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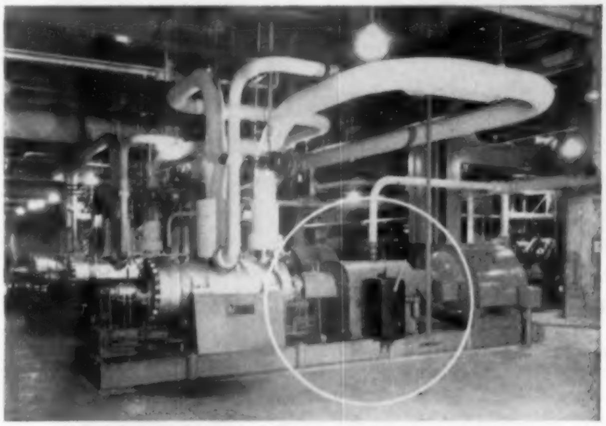
capacity to 2,682,000 kw

American Blower
Reports on
Progress in Power



American Blower Gýrol Fluid Drives control the speed of Boiler Feed Pumps at Dunkirk Steam Station. Rated capacity of each Fluid Drive is 1,250 hp at 3,500 rpm. Niagara Mohawk also uses Gýrol Fluid Drives for fan control.

Niagara Mohawk Power Corporation is one of the world's largest private producers of electrical power. With 84 hydro-electric and seven steam-electric stations, Niagara Mohawk serves a 22,000 square-mile territory in New York State, and supplies electricity to 3,100,000 people.

To keep pace with the growing power needs of its customers, Niagara Mohawk has spent a total of nearly $350,000,000 for new and expanded facilities since the war. During 1953 and early 1954, approximately 300,000 kw of generating power were added, bringing the system's total rated capacity to a mighty 2,682,000 kw.

American Blower has played an important role in this expansion program. It has supplied many of Niagara Mohawk's Stations with Mechanical Draft Fans and Gýrol Fluid Drives for boiler feed pump and fan control. Recognized for its dependability and economy of operation, American Blower equipment — including Dust Collectors, Fly Ash Precipitators and Heavy Duty Steam Coils, is used extensively in power plants throughout the country.

If you are planning to expand or modernize your facilities, get in touch with your nearest American Blower Branch Office, or write us direct. We will be pleased to work with you on your air-handling problems.

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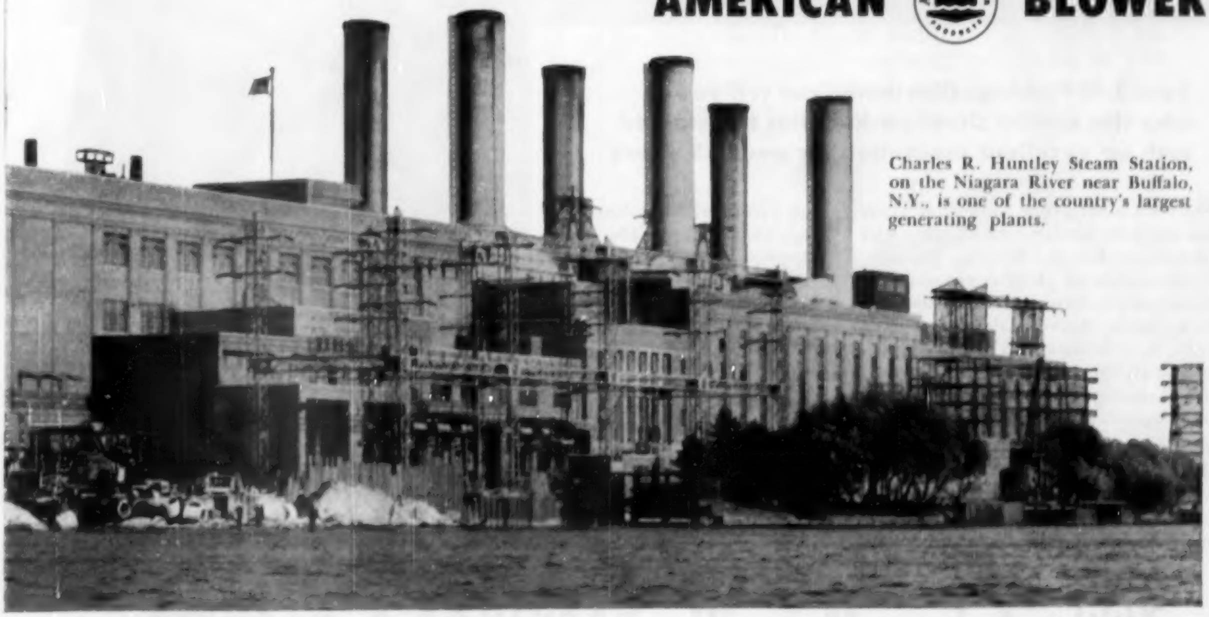

Charles R. Huntley Steam Station, on the Niagara River near Buffalo, N.Y., is one of the country's largest generating plants.

TILE • DETROIT CONTROLS • KEWANEE BOILERS • ROSS EXCHANGERS • SUNBEAM AIR CONDITIONERS

Here's a cure for two of the troubles that beset operators of stoker-fired water wall boilers.

E. Keeler Company, boiler manufacturer, has used CARBOFRAX® silicon carbide blocks, molded to fit snugly around the tubes where they connect to the headers. Since slag does not fuse to this hard, smooth material, these blocks prevent clinker build-up, protecting both the tubes and back-up lining.

The hot face of the CARBOFRAX blocks actually helps combustion. Ignition is maintained when the boiler is running at low and variable ratings. And abrasion by sharp coal particles makes so little impression that, after a test run of three years, the blocks were described by Keeler engineers as "showing no apparent wear on the furnace surface. We believe they will last almost indefinitely."

• • •

You'll find the answers to many problems of this sort in our free booklet, "Super Refractories for Boiler Furnaces." Address Dept. E-104, Refractories Div., The Carborundum Co., Perth Amboy, N. J.

Cutaway view of 500 H.P. steam generator built by E. Keeler Co., Williamsport, Pa., shows location of water wall armor made from CARBOFRAX blocks (right)

CARBORUNDUM

Registered Trade Mark

system wastes as little as 1% of the fuel, the loss amounts to $80,000, which might be two or three times the total cost of the system.

The design and construction of all components of Hagan Automatic Combustion Control systems stress durability, accuracy and ease of operation. Hagan Ring Balance Instruments provide the accurate records which enable operators to maintain top efficiencies. Truly, a Hagan System is an investment in long term economy.

Hagan engineers will be happy to discuss your Control and Instrumentation problems.

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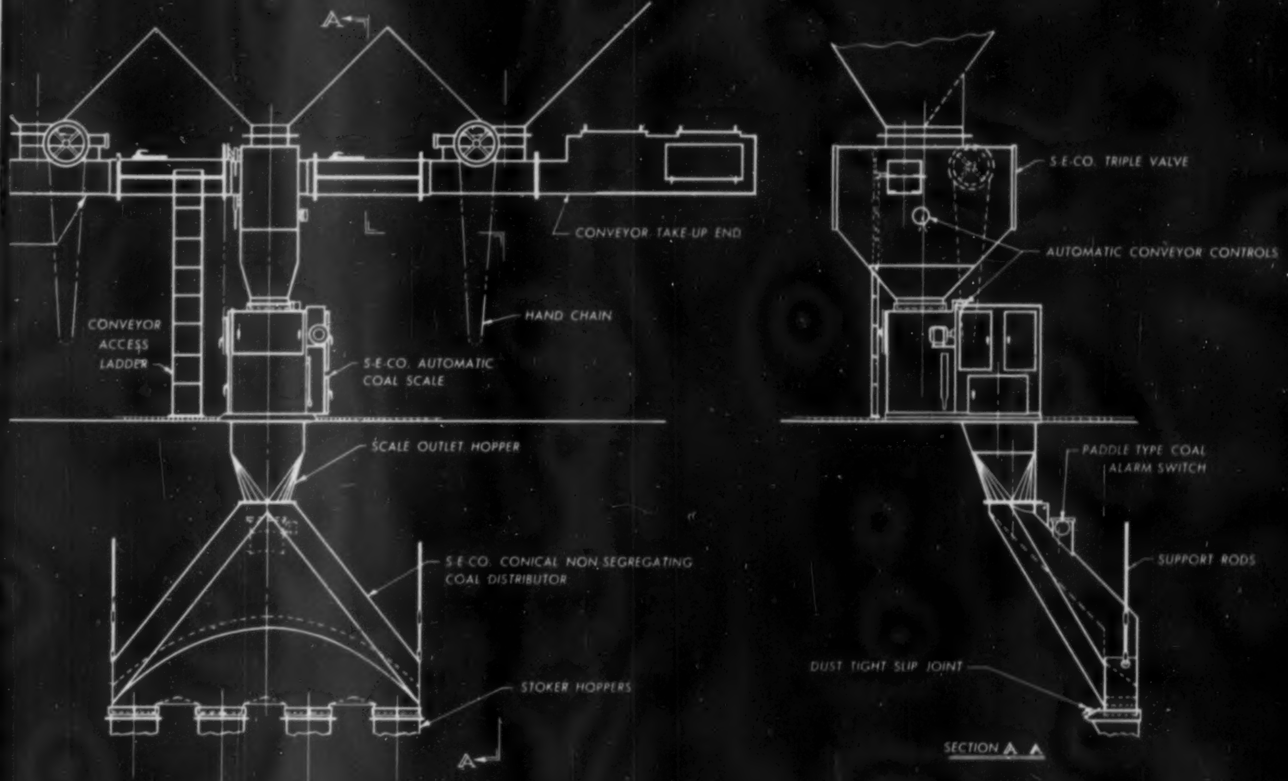

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AUTOMATIC CONVEYOR CONTROLS
PADDLE TYPE COAL ALARM SWITCH
SUPPORT RODS
DUST TIGHT SLIP JOINT
SECTION A-A

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Four words . . . but every time they appear on an order, Flexitallic salutes an engineer who has joined the crusade for one standard of quality in gasket construction.

Flexitallic Spiral-Wound identifies the original spiral-wound gasket—the standard of quality in high-pressure, high-temperature seal for more than 40 years.

Spiral-wound is the proper designation of a gasket that compresses like a spring to make an effective seal, compensates for unpredictable joint stresses, and then rebounds when the bolt load is relaxed.

Flexitallic Gaskets are exclusively spiral-wound, the uniquely resilient construction pioneered by the Company in 1912.

Each Flexitallic Gasket is engineered to meet specific conditions of thermal and physical shock, corrosion, vibration, weaving and unpredictable joint stresses. Spirally-wound V-crimped plies of required metal with alternating plies of proper filler results in a resilient gasket having characteristics of a calibrated spring.

Flexitallic Gaskets are at highest efficiency when bolted up cold at a predetermined load. For all pressure/temperature ranges from vacuum to 10,000 lbs., from extreme sub-zero to 2000° F. For all standard joint assemblies. In four thicknesses for special requirements: .125", .175", .250", .285". In diameters to 84" O. D.

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COMBUSTION

Editorials

Contrasts in Engineering Education

A part of the great American tradition in education is that it provides opportunities for individuals to make the most of their own potentialities. There has been no counterpart to the rather common European practice of highly organized central agencies to make educational policy. On the contrary, educational policy has been basically administered and oriented by local agencies responsive to community demands. This is true both at the public school level and in institutions of higher learning. Of course, there are many coordinating agencies which establish standards, but there is no single body which has a dominant voice in setting educational policy.

At the ASME Fall Meeting held in Milwaukee last month, Dr. M. H. Trytten, director of the Office of Scientific Personnel of the National Research Council, drew a contrasting picture of aims which characterize education in Russia and in the United States. One of the sharpest divisions may be seen by analyzing motivation, for Dr. Trytten pointed out that our highly trained personnel have come about almost as a by-product of individual motivation to improve personal status. National interest has had little to do directly with this motivation, whereas in Russia the interest has been consciously national, arising from the realization that education and training are necessary to the growth of Soviet power. Individual benefits have been the by-product of an educational system dominated by national interests.

In looking at the long-run picture of scientific and engineering manpower in the United States, it is necessary to understand and appreciate these distinctly different philosophies of education. Dr. Trytten quoted the following purpose of higher education from the Soviet encyclopedia:

"To prepare highly qualified politically trained engineering personnel with well-rounded education, cultured, wholeheartedly devoted to the motherland and to the course of Lenin-Stalin, capable of completely mastering and using the newest accomplishments of advanced science and technology and of merging scientific theory with the practical work of building a Communist society."

Such a philosophy is repugnant to our concepts of individual development, local control, and broad general education. But in the Cold War technology has become a part of strategic planning, and technically trained manpower is one of the most important ingredients. The American way to meet this challenge is to gain a wider understanding of the ways in which Russia is educating professional personnel without abandoning our principles of liberal and broad education. We must, as Dr. Trytten emphasized, improve science teaching at the high school level; expand the training of scientists and engineers; and adopt a consistent policy for the preservation of professional manpower.

Push Button Panacea

Some time back the Factory Mutual Association's Engineering Division called public attention to the potentially hazardous situation arising out of the widespread desire for fully automatic packaged boilers. The danger as they saw it arose from the complicated protection systems installed on these units. Accordingly they drafted a set of recommendations for both oil and gas-fired designs.

At the recent fall meeting of the ASME in Milwaukee this problem of intricate controls was the subject of an open discussion following a series of papers on automatic packaged boilers. There were many in attendance who felt the idea of fully automatic operation had been carried too far. As could be expected there were several "horrible examples" cited.

Some of these examples brought to mind the abuses of the days when safety valves were lever operated. There were frequent instances, then, where the lever arms were either weighted down or tied down because the operator was annoyed by the safety valve's popping off when he felt it shouldn't. Apparently the same manner of thinking still prevails in some plants. Elaborate controls are either strapped down or deliberately short-circuited according to some discussors.

But to our way of thinking the problem goes deeper than the dangers deliberate abuses present. The functions of the controls on any automatic unit run the gamut from the straightforward tasks of the low and high level water alarms to the rather intricate role of sequential or programming combustion safeguards. The upkeep and general maintenance of such equipment requires a broad range of skills and a high degree of understanding of the underlying functions. Bluntly stated, these requirements go way beyond the ability of the personnel in many smaller plants. Therein lies the most telling danger.

Perhaps here is an area where our national mania for push button operation could well stand a detached study by a competent engineering group. Out of such a study could come a set of recommendations on the extent and complexity of controls suitable for packaged boilers.

Corrosion Control in Industrial and Steam Power Plants

The entire range of possible corrosion problems in a power plant is discussed with solutions suggested. In addition the various suggested preventive equipment receive an analysis of applicability as well as limitations.

By RALPH M. LEMEN
The Permutit Company

DESTRUCTION of metals by corrosion presents a very serious engineering problem common to all industrial and steam power plants. In general, corrosion is caused by oxygen, carbon dioxide and low pH and frequently becomes most serious in the following locations: (*a*) boilers and economizers, (*b*) boiler feedwater circuits, (*c*) condensate return lines, (*d*) wet stages of turbines: corrosion-erosion, and (*e*) heat exchange surfaces of cooling water systems.

Boilers And Economizers

The corrosion of internal surfaces of boilers and economizers can usually be attributed to dissolved oxygen in the feedwater, although there are other causes which are frequently difficult to establish. In most cases, providing the proper boiler water alkalinity is maintained, carbon dioxide is not a factor. And in order for oxygen to be corrosive, it must be dissolved in the water. Therefore since dissolved gases are released to the steam at the inlet to the boiler drum, where the feedwater temperature increases substantially, the problem of corrosion inside a boiler is generally not too serious. However, if the velocity of water circulation through the downcomer tubes is high, the oxygen may not escape and instead be carried along in solution until the boiling temperature is reached to cause some corrosion below the water line and at the tube entrances.

Another form of corrosion sometimes found within a boiler is the phenomenon known as inter-crystalline cracking or caustic embrittlement, Fig. 1. This type of attack occurs usually where there are high concentrations of caustic soda. At high evaporation rates, where the steam formation is too rapid for replacement by circulation, a tube may become dry and all salts precipitate out of solution. With decreased loads, however, the salts redissolve in the boiler water. At the so-called "hide-out" spots the salts do not redissolve, caustic soda becomes highly concentrated and may cause inter-crystalline cracking along the grain boundaries of the metal. Caustic embrittlement used to be more pronounced in the days when boilers contained riveted seams. Welded seams have greatly reduced this type of corrosion.

The tendency toward corrosion from caustic embrittlement may be lessened by maintaining certain sulfate-carbonate ratios as suggested by the ASME, although relatively recent work and experience generally favor the more commonly accepted practice of maintaining certain ratios of sodium nitrate to sodium hydroxide. Another preventive measure is to maintain zero caustic alkalinity and to feed enough tri-sodium phosphate to react with all of the calcium in the water plus an excess for maintaining the proper pH in the boilers. Whether a boiler water has embrittlement characteristics can be determined by an embrittlement detector which has been developed by the Bureau of Mines.

The economizer, a type of heat exchanger through which the feedwater passes before entering the boiler drum to have its temperature increased by taking heat from the hot combustion gases passing to the stack, is sometimes subject to corrosion attack. High pressure economizers necessarily have steel tubes, and, unless oxygen and free carbon dioxide are completely removed from the feedwater, corrosion will occur in these tubes as the temperature of the water increases.

Removal of oxygen and free carbon dioxide from the boiler feedwater through good mechanical deaeration prevents corrosion in boilers and economizers. Many plants also follow the mechanical deaeration with chemical deaeration by feeding an oxygen scavenger, such as sodium sulfite, to the boiler water in order to remove the last traces of oxygen.

Boiler Feedwater Circuits

Corrosion of feedwater lines, pumps and valves presents a major problem because oxygen and free carbon

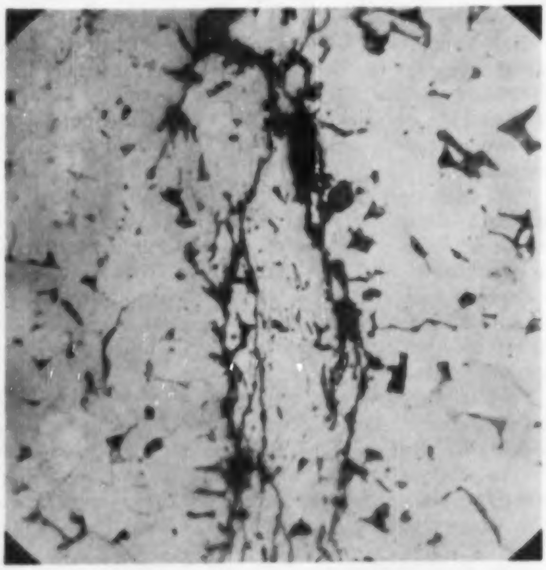


Fig. 1—Caustic embrittlement, one form of corrosion in boilers, such as pictured in above photomicrograph has come under control by proper water treatment

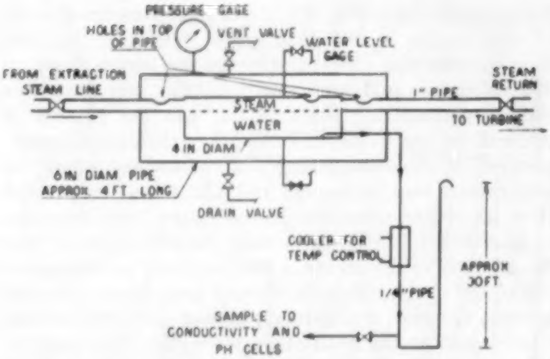
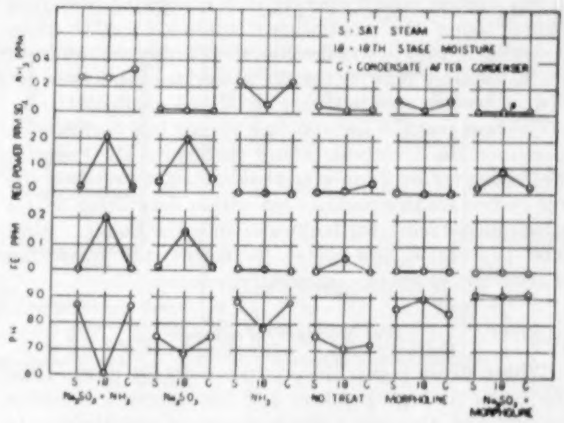


Fig. 2. Sampling technique, above, designed to obtain true samples from wet stages of turbine showed treatment results of Fig. 3, right



dioxide are present and the feedwater obtained from stage heaters is at a high temperature. In a system with a high per cent of makeup, the cold makeup may be saturated with oxygen and as its temperature increases the oxygen's corrosive action greatly accelerates. If return condensate and makeup are mixed before deaeration in the feedwater circuit, the temperature of the makeup water is increased and the feedwater line will corrode. In a feedwater system with a high percentage of returned condensate or where evaporated makeup water or other very pure feedwater is used, the pH of the water may be low, and corrosion quite active in the presence of even a very small amount of oxygen. The low pH causes iron to go into solution as ferrous hydroxide and this action continues throughout the system until sufficient ferrous hydroxide has been dissolved to raise the pH to approximately 8.3. Any oxygen present oxidizes the ferrous iron to ferric ion to form the insoluble precipitate, ferric hydroxide, which adheres to piping and tubes causing tube burnout.

Feed pumps, valves and pipe fittings are often attacked by a combination of corrosion-erosion where the water makes a sudden change in direction and where velocity is high.

An efficient deaerating heater can remove enough oxygen and free carbon dioxide from the water to prevent corrosion in feedwater lines and equipment. Since the feedwater is frequently heated to above 300 F by closed heaters and steel tubes economizers, at which temperature oxygen corrosion is very active, the oxygen in the water should be reduced by deaeration to less than 0.005 ml per liter which is commonly known as "zero" oxygen so as to eliminate any corrosion at these elevated temperatures.

Condensate Return Lines

Since, in most systems, oxygen is removed from the feedwater by deaeration, carbon dioxide generally causes return line corrosion, although oxygen is frequently drawn into the return system through valve glands where the condensation of steam forms a vacuum. The deaerator removes free carbon dioxide in the feedwater, but in the boiler itself bicarbonates and carbonates break down to give off carbon dioxide in the steam. The bicarbonate alkalinity completely decomposes in the boiler and approximately 80 per cent of the carbonate alkalinity follows suit as these equations illustrate:

$$\frac{2NaHCO_3}{100 \text{ as } CaCO_3} = \frac{Na_2CO_3}{100 \text{ as } CaCO_3} + H_2O + \frac{CO_2}{44} \quad (A)$$

$$\frac{Na_2CO_3}{100 \text{ as } CaCO_3} + H_2O = 2NaOH + \frac{CO_2}{44} \quad (B)$$

CO_2 from Bicarbonates $= 44 + (.80 \times 44) = 79$
CO_2 from Carbonates $= 44 \times .80 = 35$

For each 100 ppm of bicarbonates in the boiler feedwater, 79 ppm carbon dioxide will be given off with the steam, and for each 100 ppm of normal carbonate, approximately 35 ppm carbon dioxide will be evolved. Inasmuch as carbon dioxide is only corrosive when it is in solution very little corrosion occurs in the steam lines, but it frequently occurs in the condensate return lines. Here is how. The carbon dioxide lowers the pH of the condensate which causes corrosion of the condensate lines and iron pickup. This iron travels through the feedwater cycle and back to the boiler to form an iron deposit on the piping and boiler tubes.

Sometimes ammonia is added to the boiler feedwater to raise the condensate's pH thus reducing the corrosion caused by the acid condition. Ammonia evaporates in the boiler, passes off with the steam and re-dissolves in the condensate. This re-dissolved ammonia neutralizes the carbon dioxide and thus protects the return lines and prevents iron pickup. It is quite important, however, that oxygen be removed completely from the system if ammonia is used. Ammonia, in the presence of any oxygen, corrodes copper and, therefore, brass or copper parts in valves and condenser tubes would be subject to attack. In fact, high concentrations of ammonia will attack copper without any oxygen being present.

In recent years amines have been used in place of ammonia to neutralize the carbon dioxide in the condensate. Organic amines such as cyclohexylamine and morpholine readily volatilize with the steam in the boiler, and re-dissolve in the condensate to raise the pH and protect the return lines. Unlike ammonia, the amines will not attack copper, and, therefore, prove more desirable than ammonia except for the fact that the amine treatment is considerably more expensive. Because of the cost, it is practical to use amines only where the feedwater is low in free carbon dioxide and bicarbonate alkalinity and where the feedwater makeup is very low. More recently, filming type amines have been placed

on the market which operate in a completely different manner from the neutralizing amines. Rather than neutralizing the carbon dioxide, the filming amines form a non-wettable film on the metal surfaces and thus act as a protective area between metal and condensate.

The best method for avoiding return line corrosion is to reduce the bicarbonate and carbonate alkalinity in the feedwater by proper treatment and to remove the free carbon dioxide and oxygen with a deaerating heater before introducing the feedwater into the boiler. With good deaeration and water treatment, the quantities of ammonia or amines are greatly reduced.

Wet Stages Of Turbines

Where steam is used to produce power it passes from the boiler at high pressure and high superheat into a turbine and through various stages of the turbine to the surface condenser. Condensate is then pumped back to the boiler through several stages of closed heaters with usually a deaerating heater serving as one of the stage heaters. Bled steam is taken off at various turbine stages to heat the water as it passes through the stage heaters. Makeup water is added to the system from evaporators or from ion exchange demineralization equipment. The alkalinity of the water is substantially zero and therefore there is no breakdown of alkalinity in the boiler to give off carbon dioxide with the steam.

Because of the high purity of the water, oxygen must be completely removed from the cycle. Surface condensers can be furnished to effect partial deaeration of the condensate under favorable conditions, but this usually is not sufficient for full protection of the feedwater circuit, and for this reason a deaerating heater is used as one of the stage heaters.

Sodium sulfite is often added to the boiler water to scavenge the last traces of oxygen not removed by the deaerating heater. However, at high pressures, the sulfite decomposes to give off sulfur dioxide in the steam which re-dissolves in the condensate and forms sulfurous acid. This lowers the pH of the condensate and results in corrosion-errosion and iron pickup in (1) the wet stages of the turbine, (2) the surface condenser and (3) condensate feedwater lines back to the boiler. Many power stations feed ammonia to the boiler feedwater to neutralize the effect of sulfur dioxide in the condensate. However, it takes a lower temperature for the ammonia that passes off with the steam from the boiler to re-dissolve in the condensate than is the case with the sulfur dioxide. As a result serious corrosion occurs in some of the wet stages of the turbine even though sufficient ammonia is present in the steam to neutralize the acid condition.

This fact was substantiated by a survey[1] at the Mystic Station of the Boston Edison Co. There they had found a considerable amount of corrosion-erosion in the wet stage areas of one of their turbines, even though proper pH was being maintained at their boiler feed pump suction through the feeding of ammonia to the boiler water. During the course of the survey, it was necessary to determine the composition of the moisture formed in the turbine. This meant removing the steam-water mixture from the turbine stages and separating the water from the steam for testing. So as to duplicate conditions in the turbine the condensate was removed from contact with the steam before cooling by a sampling apparatus shown in Fig. 2. Tests were then conducted and the results at the 18th stage indicated that the sulfur dioxide was concentrating in the liquid phase to form sulfurous acid and, further, that ammonia was partially neutralizing the acid but was not present in sufficient amount to increase the pH to the desired range. However, at subsequent stages of the turbine where the temperature was decreased and the liquid sub-cooled below its steam saturation temperature, the ammonia did dissolve into the liquid to raise the pH. A study was then made as to the effects of feeding these various chemicals to the cycle. Results showed that when ammonia feed was stopped, the reducing power and iron content of the liquid at the 18th stage were still high, and the pH around 6 to 7. By using ammonia only without sulfite, the reducing power and iron pickup were zero.

The best treatment up to this point indicated the feeding of ammonia without sulfite in the boiler water, but this meant the loss of the protection of sulfite as an oxygen scavenger. Various amines were then considered, and the findings showed that sulfite treatment together with morpholine in place of the ammonia gave the best protection, Fig. 3. The pH at the wet stages had the same pH as the steam from the boiler, the reducing power was much lower, and the iron pickup was zero throughout the cycle. Morpholine re-dissolves in the liquid phase of the turbine as readily as the sulfur dioxide, and therefore the lowering of the pH does not occur in the wet stages of the turbine.

The Coughlin Steam Electric Station of the Central Louisiana Electric Co.[2] is another plant that reports success with morpholine. All makeup (about 1 per cent) for their system comes from evaporators discharging vapor to the deaerating heater. Initially, untreated well water was fed to the evaporators but they found undesirably high amounts of carbon dioxide in the system as a result of the breakdown of alkalinity in the water. Water treating equipment, consisting of acid regenerated zeolite followed by degasifier and caustic soda neutralization, was then installed for removal of the excessive high carbon dioxide. This gave considerable improvement to their problem but a small residual of carbon dioxide still remained in the system. Finally the feeding of morpholine was adopted which reduced the carbon dioxide in the system to zero, and the iron in the feedwater read consistently 0.1 ppm or less.

Because sodium sulfite is a source of condensate return line corrosion, engineers have, in recent years, been seeking another oxygen scavenger that would eliminate the acid condition resulting from the presence of sulfur dioxide in the steam. Hydrazine has been used in a few plants in this country recently with considerable success. Hydrazine reacts with oxygen to produce water and nitrogen, and, therefore, there are no solids formed which would increase the solid content of the boiler water.

$$N_2H_4 + O_2 \rightarrow N_2 + H_2O$$

The Duke Power Company[3] has had a very successful experience with hydrazine in their high pressure boilers, and they have set up a program of feeding this chemical to all of their units including two 1850 psig boilers. One of the limitations of hydrazine is that it is quite expensive as compared to sodium sulfite (approximately \$1.25 per lb compared to 3¢ to 4¢ per lb for sulfite)

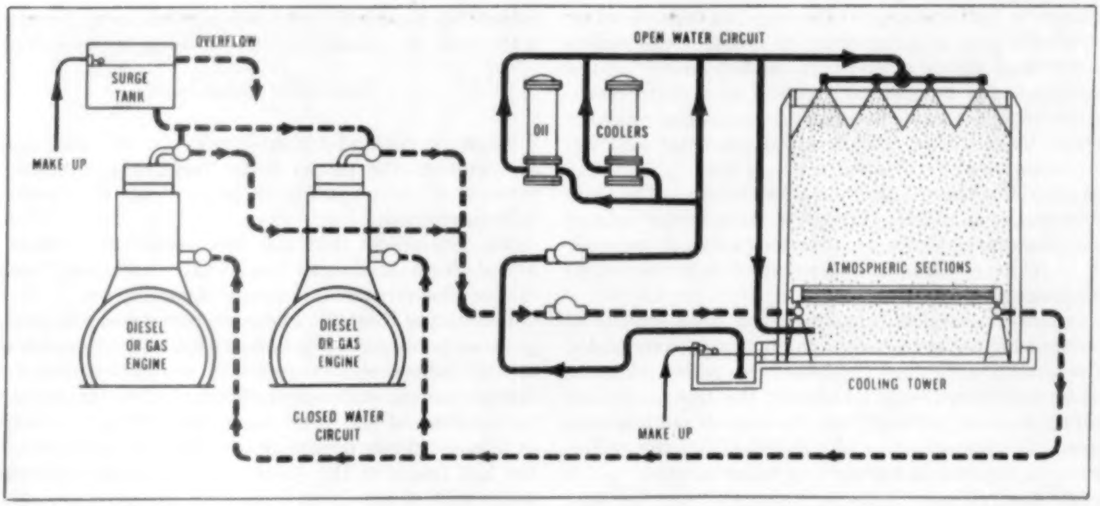


Fig. 4—Simplified layout of both an open and a closed cooling water circuit permits an understanding of how the two systems differ. In the open circuit on the right oxygen pickup from the air is strong and corrosion prevention steps needed

although it requires only approximately $^1/_8$ the amount of hydrazine as compared to sodium sulfite. Also it may break down to form ammonia, and any copper in the water may act as a catalyst for this reaction.

Most engineers prefer to feed an oxygen scavenger following a deaerating heater to remove the last traces of oxygen. However, with the advent of the reboiler type deaerator where "zero" oxygen in the effluent water is accomplished, the feeding of sodium sulfite or hydrazine can often be omitted.

Heat Exchange Surfaces of Cooling Water Systems

Of the two basic types of cooling water systems, namely, the once-through and the circulating system, the one most commonly employed in industry today is the circulating system where the cooling water is used over and over again in order to conserve the available supply of water. The once-through system is only used where rivers, lakes or ocean afford unlimited water.

The circulating system can be either the open type or the closed type, Fig. 4. In the open type, the heat picked up by the cooling water in passing through the heat exchange equipment is released through evaporation by passing the water through spray ponds, natural draft or mechanical draft cooling towers. The open system is used generally for large installations such as process cooling in the petroleum industry, and surface condenser cooling in steam power plants. The closed system is one in which the heat that is absorbed in passing through the heat exchange equipment is released in another heat exchanger by some other source of cooling water, and this system has application for cooling jackets.

In any cooling water system, the engineer is concerned with the prevention of excessive deposits of scale which decrease the heat transfer rate of the cooling surfaces, and the prevention of corrosion or erosion of the metallic parts of the system. Whether a water has a tendency to form calcium carbonate scale can be predicted by the Langelier Index which takes into account the following factors: (*a*) calcium hardness, (*b*) total alkalinity, (*c*) pH, (*d*) total dissolved solids, and (*e*) temperature of the water.

Each of these factors except dissolved solids increase the scale-forming tendency of the water, whereas dissolved solids have a tendency to reduce scale formation. The Langelier Index measures the difference between the computed pH_s, called the pH of saturation, and the actual pH of the water. The computed pH_s is derived from the Langelier equation which contains certain numerical values obtained from tables based on the above five factors. This value is then subtracted from the actual pH to give the Index figure. If the Index is a minus value, corrosive tendencies are present and if the Index figure is a plus value, scale-forming is likely.

Usually the temperatures of the water in the cooling system are fixed, and it becomes necessary to consider the reduction of calcium hardness, total alkalinity, and pH if the water deposits an excessive amount of scale in the system. Cold lime treatment can be employed for reduction of calcium alkalinity, and then further treated with acid to reduce the pH and total alkalinity. It may be necessary also to feed soda ash if the calcium hardness is quite high. If the water is clear and the hardness is high, straight zeolite softening can sometimes be used to reduce scale formation. Frequently just acid treatment alone is used where the water has a high alkalinity and a relatively low total hardness.

If water treatment completely eliminates scaling of the water, the metal surfaces might then be subject to attack by corrosion which is equally undesirable. The Langelier Index serves a very useful function in this respect in that the cooling water can be treated to give a slightly positive Index so that a uniform thin film of calcium carbonate scale is deposited on the metal surfaces. This is known as the "controlled scale" treatment and is widely used in inhibiting corrosion in cooling systems. This film gives protection against corrosion, and since it is very thin it does not reduce the heat transfer rate of the exchange surfaces to any great extent. However, since temperatures vary throughout the cooling system, the Index will be changed in various parts of the cycle from perhaps a slight scale-forming tendency to a slightly corrosive condition because of a reduction in

temperature. Therefore, in choosing the type of water treatment to use, it is necessary to consider the results that will be produced at all points in the system. Often a treatment may be selected that will have slight corrosion tendencies at those points where corrosion-resistant alloys are used, and an indication of slight scale formation at locations where ferrous surfaces are used.

Another treatment for prevention of excessive scale and corrosion in a once-through system is the feeding of phosphate to hold the scale-forming solids in solution. This is relatively simple but requires that the entire cooling water stream be treated.

In an open circulating system, the only stream of water that has to be treated is the makeup water added to the system to replace the losses due to evaporation, windage and blowdown. However, the treatment and handling are more difficult than the once-through system because the concentration of total solids in the water, due to evaporation in the cooling tower or spray pond, must be controlled by a proper balance of windage and blowdown. The Langelier equations can be applied to indicate whether the water is scale-forming or corrosive, but the Langelier Index must be based on the circulating water and not on the makeup water added to the system.

In a closed circulating system, there is no evaporation of the water and, therefore, no concentration of the solids. The makeup requirements to the system are quite small because the only loss is that due to leakage around pipe fittings and valves. Due to this small amount of makeup scale formation is small, and therefore the main concern is corrosion.

In systems where the surfaces must be kept entirely free of any scale and at the same time protected against corrosion, inhibitors such as chromate can be used. In open circulating systems where the water is aerated in passing through a cooling tower or spray pond and becomes saturated with oxygen, vacuum deaeration is sometimes considered for removing this oxygen from the water but the circulating stream must be deaerated.

Equipment Requirements

Since oxygen and carbon dioxide are the chief causes of corrosion, the proper water treating equipment for removal of these gases must be available if corrosion is to be prevented.

The equipment that can be considered for their removal from feedwater are: (*a*) deaerating heater, (*b*) open heater, and (*c*) vacuum deaerator.

Deaerating Heater. The solubility of non-condensable gases such as oxygen, carbon dioxide and nitrogen is zero at the boiling temperature. A deaerating heater accomplishes the removal of these gases by bringing the temperature of the water up to the boiling temperature at a given steam operating pressure and scrubbing out the last traces of the gases by an intimate mixture of water with steam.

The reboiling type deaerating heater, Fig. 5, deaerates water in three stages. The first stage is primarily a vent condenser for concentrating the noncondensable gases and condensing a major portion of the steam being vented to the atmosphere. In the second stage, the water is heated almost to steam temperature by spraying it into a steam atmosphere. Approximately 95 per cent of the oxygen and most of the free carbon dioxide are removed from the water in this stage, and the partially deaerated water is then delivered to the third stage known as the reboiler or steam scrubber. Final and complete deaeration is accomplished in this stage by the fresh oxygen-free steam being introduced into a long, narrow compartment so constructed as to insure an intimate mixture of steam and water to produce a violent boiling and vigorous scrubbing action. The water from the second stage is uniformly distributed into the bottom of the reboiler or steam scrubber by a water distributing

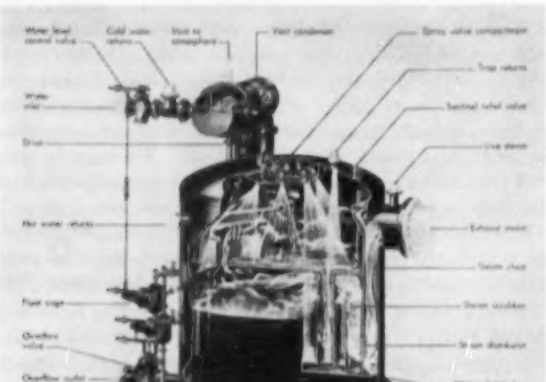


Fig. 5—The reboiling type deaerator not only eliminates dissolved oxygen but provides for a considerable increase in the pH value of the water

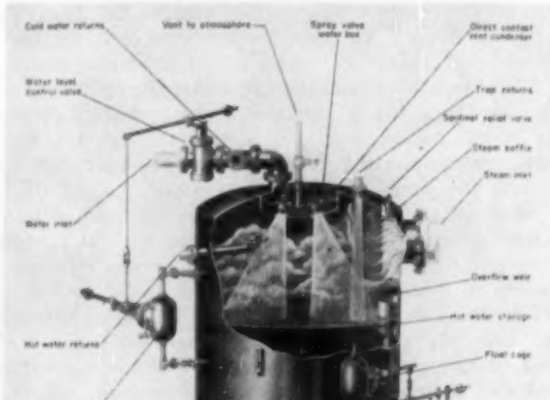


Fig. 6—Spray Type open heater removes less oxygen than the reboiling design, Fig. 5, but costs less. It works well for low pressure boilers

TABLE I. DEAERATOR PRESSURE EFFECT ON pH

Case	Capacity of Deaerator, Lb per Hr	Steam Pressure for Deaeration, Psig	M. O. Alkalinity of Effluent, Ppm vs. $CaCO_3$	Influent pH	Effluent pH
1	60,000	1	10	5.6 to 6.0	8.4
2	200,000	5	18	6.6 to 7.4	8.7
3	1,400,000	14	16	6.8	8.9
4	200,000	28	18	7.4 to 7.8	9.4
5	750,000	120	11	6.4	10.1

TABLE II—DEAERATOR REMOVAL OF CO_2 AT 120 PSIG

Deaerator Influent, Ppm				Deaerator Effluent, Ppm					
								Total	
Free CO_2	HCO_3	CO_3	Total CO_2	Free CO_2	HCO_3	CO_3	OH	CO_2	pH
1.0	11	0.0	10.7	0.0	0.0	5	6	2.2	10.1

distributor plate. The steam distributor consists of perforated horizontal rows through which the steam enters and intimately mixes with the water from the second stage. At low load, all of the steam passes through the upper rows of perforation so that the scrubbing action is uniform throughout the full operating range of the deaerator. The completely deaerated water and steam separate at the top of the deaerating scrubber section with the water spilling over into the storage section and steam passing to the second stage for heating the incoming water.

The first stage or vent condenser can be either the old conventional tubular type, Fig. 5, or the newer internal direct contact type. The external tubular type is essentially a tubular heat exchanger with the influent cold water acting as the cooling medium for condensing the steam vented from the second stage of the deaerator. The condensed steam is returned to the deaerator and the non-condensable gases are discharged to atmosphere with only a wisp of steam wasted.

The internal direct contact type of vent condenser has a number of advantages over the conventional external tubular type. It consists of a compartment for collecting the non-condensable gases which is isolated from the second stage or spray section. The steam and non-condensable gases come in contact with the cold water from the spray valves on their way to this isolated internal compartment and most of the steam condenses while gases go through to collect in the vent condenser compartment. This compartment provides for a quiescent zone completely segregated from the high turbulence of the steam atmosphere in the second stage of the deaerator and, therefore, there is little tendency for the non-condensable gases to be dragged back into the second stage or spray section. A vent opening is provided for discharging these gases to the atmosphere.

A reboiler type deaerating heater not only eliminates the dissolved oxygen in a water, but also provides for a considerable increase in the pH value of the water. Carbon dioxide is practically the only gas found in water that causes a low pH. If there is free carbon dioxide present in the water, the pH will be less than 8.3; however, a pH of 8.3 indicates that all of the free carbon dioxide as determined by the American Public Health Assn. Titration Method is removed. Table I shows that the effluent water from a reboiler type deaerator has a pH of from about 8.4, for an operating pressure of 1 psig, to as high as 10.0 for an operating pressure of 120 psig. This higher pH value is accomplished by the fact that additional carbon dioxide is removed by deaeration beyond that present as free carbon dioxide because of the dissociation of the bicarbonate radical.

The effectiveness of carbon dioxide removal by deaeration at one plant, where the deaerator was operated at 120 psig steam pressure, is shown in Table II. All of the free carbon dioxide has been removed as well as all of the bicarbonate alkalinity. Also, more than half of the carbon dioxide of the normal carbonate alkalinity has been changed to hydroxide indicating nearly half of the carbon dioxide of the normal carbonates has been removed in the deaerating heater.

These tests show very clearly that the higher the temperature or steam pressure, the greater is the increase in pH by deaeration. A deaerating heater, therefore, will not only remove all of the oxygen and free carbon dioxide, but will give a pH value above 8.3 which provides for maximum protection against corrosion.

The amount of deaerated water storage incorporated into a deaerator design depends upon the amount of controlled and uncontrolled water entering the deaerator. If there is returned condensate available for boiler feedwater, this water should be deaerated and should be introduced into a deaerator uncontrolled. In order to provide sufficient space for surges of uncontrolled returned condensate, 10 minute storage capacity is generally provided if the returned condensate amounts to 60 per cent or more of the total influent water. If the condensate return amounts to 30 per cent to 60 per cent of the total influent water, 7 minute storage is quite often recommended. For condensate returns up to 30 per cent, 3 to 5 minute storage is generally sufficient. If there are no condensate returns and the water entering the deaerator is 100 per cent controlled makeup water, then 2 minute storage capacity is satisfactory.

There are other types of deaerating heaters, such as the tray type, where the water is heated and deaerated by cascading down over a series of trays in an atmosphere of steam and the jet atomizing type where the water is delivered into a high velocity steam jet, and is broken up or atomized by the steam.

Open Heater. The spray type open heater, Fig. 6, is not as efficient for oxygen removal as a deaerating heater since this unit does not incorporate the deaerating scrubber section. The water is sprayed through stainless steel spray valves into a steam atmosphere, as in the case of a deaerating heater, but this heated and partially deaerated water is then delivered directly to the boiler feed pump suction. The water is heated to within one degree to three degrees of the steam temperature, and the oxygen is reduced to 0.1 to 0.3 ml per liter.

The open heater is less expensive than a deaerating heater and can often be used where complete oxygen removal is not required as in the case of low boiler pressures where stage heaters and economizers are not used.

Vacuum Deaerator. The fundamental principles that apply to deaeration at high temperatures also apply to vacuum or cold water deaeration, the difference being that instead of increasing the temperature of the water to the boiling temperature by means of steam, a vacuum is produced so the water boils at its low temperature.

The vacuum deaerator consists of a steel tank incorporating a stack of either Raschig rings or wooden slats. The cold water enters the top of the tank through a pipe distributor and cascades down over the staggered trays or rings which break the water into thin films and expose

a large water film area so that the non-condensable gases may escape from the water at the boiling temperature. These gases, in addition to some water vapor, are removed from the deaerator by either multi-stage steam jet ejectors or vacuum pumps which also maintain the proper vacuum in the tank so that the water will boil at its given temperature. Oxygen residual in the effluent water of approximately 0.3 to 0.5 ml per liter generally is quite satisfactory although more complete removal can be obtained if the particular conditions require it. Free carbon dioxide in the water can be reduced to approximately 2 ppm by vacuum deaeration. Complete removal of oxygen and carbon dioxide is not required at low temperatures as in the case of the higher temperatures where corrosion is very much more active.

Removal of carbon dioxide present as bicarbonates or carbonates in the water can be accomplished with any one of the following methods of treatment, depending upon the degree of alkalinity reduction desired: (*a*) lime-soda softening, (*b*) sodium zeolite softening followed by acid treatment, (*c*) hydrogen zeolite followed by caustic treatment, (*d*) hydrogen and sodium zeolite treatment, (*e*) dealkalization, and (*f*) demineralization.

Conclusion

Since the causes of corrosion in boilers and feedwater cycles are generally well recognized these days, it is possible to control and minimize the wastage of metals resulting from such phenomena by installation of the proper water treating equipment and attention to correct operation of the equipment. The initial cost plus operating expense of such equipment are generally quite insignificant when compared to the savings that are realized as a result of fewer plant shutdowns, less maintenance costs and lower replacement costs.

This nation's dwindling supply of raw minerals behooves all industry to stop the destruction of metals by giving full attention to proper corrosion control. In all fairness to industry in general the more progressive managements are initiating full-scale corrosion control programs wherever they apply.

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Steel Engineers Convene at Cleveland

In a four day meeting at the Cleveland Public Auditorium, September 28, 29, 30 and October 1, the Association of Iron and Steel Engineers combined their annual convention with the Iron & Steel Exposition. The convention proper included sessions in most of the major fields of interest for the steel engineers. One, labeled the Combustion Session, featured material in the power field.

New Power Works

J. P. Katzenmyer, project engineer, U. S. Steel Corp. reported on "New Power, Steam and Blowing Installations at Ohio Steel Works." This particular plant found itself at the close of World War II with facilities of so antiquated a vintage that immediate replacement was necessary to avoid curtailing production. In fact the author reports so rapid a rate of deterioration during the construction period that it was often questionable whether the new facilities would be in before the old became inoperative.

This paper covers a complete description of the problem, the temporary solutions, the final solution, the new equipment installed, and the interesting sidelights in connection with the many problems involved when new equipment is installed in an existing plant without loss of production.

Power Plant Reports

Stanley A. Nelson, supervisor of plant engineering, Deere & Co. delivered a paper, "A Power Plant Report to Management", framed around four vital questions:

1. Why keep records and make reports?—Records and reports tell how well operations are being carried on and what the costs of the various services and utilities are. They transmit information and prove to the person and his employer that he is doing a good job.

2. What should go into reports?—Only the minimum information needed for guiding the operation and maintenance of a power plant or using the utilities to best advantage should be included. Records and reports should be concise and useful.

3. When should reports and records be avilable?—In order to be of most value, records and reports should be available as soon as possible after the data is taken. Otherwise, the reports serve only as historical data.

4. What should be done with them?—Engineers should study the results to determine what economies can be effected by careful operation of equipment or by the installation of new or modernized equipment

Changes in Gas Composition

Edwin X. Schmidt, development supervisor, Cutler-Hammer, Inc. discussed "The Effect of Changes in Gas Composition on the Utilization of Fuel Gases."

Changes in gas composition frequently interfere with satisfactory utilization of fuel gases. The undesirable effects on combustion behavior can frequently be reduced or eliminated by adjustments of gas burning equipment. It is also possible to control changes in fuel gas composition to reduce objectionable combustion behavior.

A procedure is offered which should be of value in a better understanding of the subject. In this procedure, those properties of gas which affect combustion behavior are ascribed to each gas and presented in graphic form.

Fig. 1—New plant covers approximately 12 acres of a 250-acre tract and its single story brick construction houses 500,000 sq ft of floor space. Water supplies are ample and coal and power are available at attractive unit cost charges

Spreader Stokers Meet Textile Plant Load

By A. KEITH POOSER

General Engineer, The American Thread Co.

LEO M. COHAN

Combustion Engineering, Inc.

The new Sevier, N. C. plant of the American Thread Co. close to the southern coal fields, selected spreader stokers for its boiler plant. Early performance tests indicate remarkably uniform CO_2 and outlet gas temperatures over wide load swings.

THE American Thread Company, manufacturer of threads and yarns for various purposes, was organized in 1898 with its principal mills located in New England. Today only two of these original mills, one at Willimantic, Conn., and a spool mill at Milo, Me., are in operation. They have gradually given way during the last twenty-five years to newer mills built or purchased in the South where the company now has seven in operation. The latest of these is the Sevier, N.C., finishing plant dedicated in June of 1953. The general offices of the company are in New York City.

The new Sevier plant is of single story brick construction, Fig. 1, with steel framework and boasts a 500,000 sq ft floor space. Site of the new plant, which covers approximately 12 acres of a 275-acre tract abutting the Blue Ridge Mts., was chosen because of its ample water supply for process operations, the availability of coal and of power at reasonable rates and good transportation facilities which made the site attractive.

Water Supplies

Raw water of good quality comes from Armstrong Creek, before its junction with the north fork of the Catawba River, through two 1500-gpm pumps whose suction intakes are protected by traveling screens. This water source supplies all plant process needs as well as drinking water requirements but only after the water has passed through the filter plant.

This filter plant comprises, first, flocculating basins, then, settling basins and, finally, sand filter beds. In addition the plant is so located that a 1,000,000 gallon concrete reservoir, 120 by 150 ft. (top dimensions) by 10 ft deep, connected to the water system, has an effective head of 80 ft over the mill floor, enough to insure a 35-psi static pressure at all times within the plant. The 1,000,000 gallons, incidentally, divide among the three major requirements in this way—500,000 gallons for plant use, 130,000 gallons for sprinklers, 370,000 gallons for fire protection.

Coal Handling

The plant's location, close to the southern coal fields, made bituminous coal the ideal choice for fuel. As a result two 47,000-lb-per-hr stoker-fired boilers were selected. Their description appears below.

The coal reaches the plant by railroad. The individual coal cars dump their loads onto a grizzly grate and from there coal falls into an unloading pit. From here the coal moves by conveyor to a bucket elevator, Fig. 2. The buckets then transport the coal to a covered silo of

Fig. 2—Bucket elevator moves up to 40 tons per hr of coal into a 250-ton covered silo with both dead and live storage.

Fig. 3—Firing aisle of boiler room reveals cleanliness from a fully-enclosed drag-bar conveyor feeding coal to stokers

250-ton total capacity divided between live and dead storage space. This coal handling system can move up to 40 tons per hr.

Within the plant proper coal is drawn from the live storage space in the silo onto a drag bar conveyor for movement to the individual spreader stoker hoppers. Fig. 3 shows the dust-free boiler room and firing aisle this enclosed coal handling presents. Another view of this firing aisle appears on the cover.

Spreader Stoker Design

When the firing method was selected the choice was spreader stokers to take advantage of their proved ability to handle a range of coals. The particular stoker chosen was the completely redesigned Combustion Engineering, Inc. overthrow, unit-drive spreader stoker.

The stoker at American Thread Co., Fig. 3, consists of three spreader units. Each unit features a rotary-scraper feeder coupled to a wide hopper throat. Coal flows from the hopper to this feeder by gravity. The feeder rotor, a fixed steel drum over which steel scraper flights revolve, meters the coal from hopper to distributor. The amount of fuel metered to the distributor depends upon the space between the scraper blades and the cutoff gate, Fig. 4, and the speed of the scrapers. The rotary feeder delivers coal in a uniform manner and overcomes the objections to intermittent or slug-feeding methods.

A built-in motor comes with each spreader unit. It has a Roto-Cone variable speed pulley on one shaft extension for distributor speed control and a Graham variable speed transmission on the other shaft to provide continuous speed regulation for the rotary feeder, Fig. 5.

Distributor speed can be set to give a uniform fuel distribution over the depth of the furnace. Once properly set further adjustments need not be made unless there is a change in sizing or moisture content of the coal. Fine, or dry coal, for example, requires a greater distributor speed than coarse or wet coal.

The feeder speed, of course, needs to be regulated to suit the load requirements and the Graham variable speed transmission does this either manually or automatically. This continuous speed drive for feeder operation assures a uniform flow of coal to the distributor even with a wet, fine coal. The linear characteristic of the drive is ideally suited for combustion control.

Further, since each spreader unit has its own drive mechanism, speeds of both distributor and feeder may be varied at will compared with other units on the stoker front. This provision can correct any possible hopper segregation by regulating individual spreader outputs to give an even burning fuel bed.

Performance Tests

Before the manufacturing plant had been completed Unit No. 1 in the boiler room was put through a series of three tests. Each of these tests ran four hours and began after the fires were cleaned and the ashes pulled. The test runs were concluded when the fires were cleaned again. Table I shows the results of these tests which are discussed more fully below.

Gas samples were taken at the boiler outlet on centers of equal thirds of the duct. Thermocouples attached to the sampling tubes supplied temperature data at these points. Additional thermocouple inserts at the air heater gas outlet and in the windbox completed the temperature data. Dust samples were collected by an Aerotec sampler but at the stack outlet rather than at the inlet to the main dust collector so that a check could be run on the actual stack dust emission.

Since so small a quantity of flyash reached the sampler at the 40,000 lb per hr rating on the boiler (0.66 lb per 1000 lb of flue gas) a collector efficiency of 85 per cent was assumed for the lower test loads. The dust collector catch was weighed and refuse to the stack calculated on these latter tests. For the 25,000 lb per hr test, Table I, dust loading ran 0.35 lb per 1000 lb of

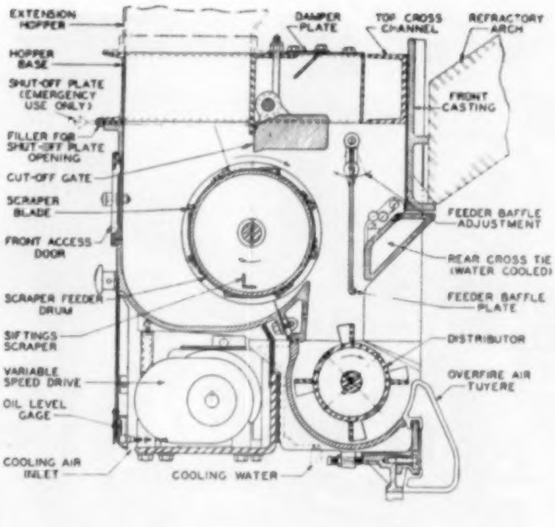


Fig. 4—Sectional view of the spreader unit labels various working elements and illustrates overthrow feed feature

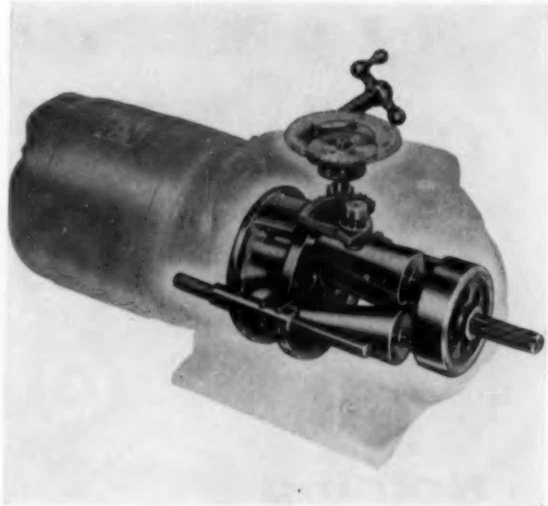


Fig. 5—Structural assembly of the spreader unit drive shows tapered rollers, the speed control wheel and main motor

flue gas. Both runs in Table I gave dust loadings well below the ASME recommended limitation of 0.85 lb per 1000 lb of flue gas.

TABLE I—PERFORMANCE TEST RUNS, NO. 1 BOILER, AMERICAN THREAD CO., SEVIER, N. C.

	Predicted		Test
Evaporation	40,000	37,600	25,000
Grate heat release	453,000	414,000	268,000
Fuel Rate (calculated)	3,630	3,290	2,080
Drum Press	200	172	160
Draft losses:			
Furnace draft	0.10	0.13	0.15
Boiler	0.66	0.68	0.33
Air heater	1.05		
Dust collector	1.55		
Duct	0.50		
Total	3.86		
Temperatures:			
Boiler outlet gas	570	576	485
A.H.O. gas	405	404	336
A.H.O. air	285	304	265
CO_2	13.8	13.9	12.8
Efficiency	82.8	82.9	86.08
Test rating		37,600	25,000
Proximate analysis:			
Fixed carbon	56.4	56.3	57.0
Volatile	31.8	31.4	32.2
Ash	8.4	8.5	7.0
Moisture	3.4	2.7	2.7
Sulfur		1.1	1.1
Btu/lb as fired	13,500	13,850	14,100

Coal samples were pulled throughout each test at hourly intervals. The samples were quartered for analyses. Separate moisture samples were taken from the as-fired fuel. Quartered ash samples were obtained from each of these ash hoppers and analyzed separately for combustible and moisture content. Likewise refuse from collector hoppers was sampled and analyzed.

Calculations follow the ASME short form as nearly as practical. Since accurate coal weighing was difficult coal weights were determined from heat balance efficiency and Btu output. Carbon loss was calculated from known factors including weighted refuse to ash pit and collector, percentage combustible in respective refuse samples and relative ash distribution.

Considerable incidental data was compiled at this same time but is not reproduced in this article.

Test Results

A study of Table I comparing predicted against actual performances reveals the effectiveness of the equipment. The CO_2 and the temperature readings across the boiler outlet were remarkably uniform. (See Fig. 6.) Such a uniformity of CO_2 and outlet gas temperatures indicates a freedom from stratification of furnace gases resulting from a uniform fuel distribution, and a proper furnace design.

At all loads the stack was a No. 1 Ringelmann or better. To maintain this stack, excess air quantities had to be raised slightly for the low load tests above those for the rated output test run.

The points labelled on Fig. 6, below, as Left, Center, Right represent the physical positions of the sampling devices across the boiler outlet duct. This duct measured 12-ft across and the samples were taken on centers of equal thirds of the duct. As a result the Left position represents a point 3-ft in from the edge of the duct. The Center point is 3-ft further in or 6-ft from the outside duct edges and the last sampling takeoff, Right, 3 ft from the right edge of the duct. The values carried on Fig. 6 are averages of all readings at these traverse points for the tests indicated.

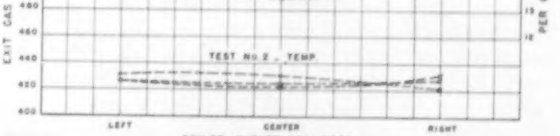
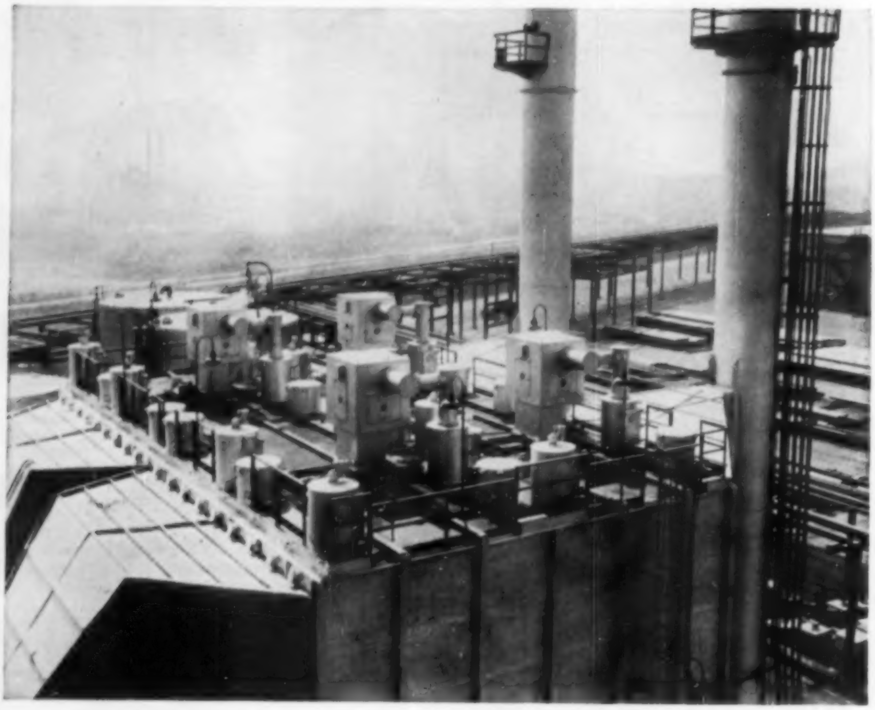


Fig. 6—Performance curves of tests in Table I demonstrate the even temperature and CO_2 results across the boiler outlet



Interpreting Graphitization for Power Engineers

By HELMUT THIELSCH

Metallurgical Engineer, Grinnell Company, Providence, R. I.

The power industry has been vitally concerned with graphitization ever since the brittle failure in a welded carbon-moly steel pipe in the main steam line at the Springdale Station of the West Penn Power Company in January 1943. The author presents a method for evaluating severity of graphitization and provides recommendations and techniques for rehabilitation.

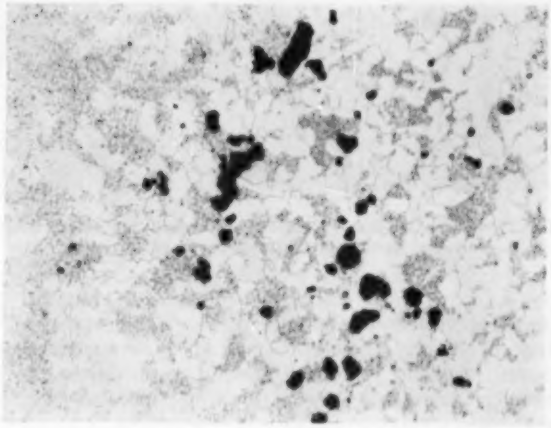


Fig. 2—Photomicrograph of the graphitized zone in the cracked valve material shown in Fig. 1. Heat-affected zone on left; base metal on right (500×)

BECAUSE severe graphitization reduces considerably the ductility and toughness of the affected areas, periodic examination of valve and pipe joints in high-temperature piping is essential to prevent costly failures and contingent danger to life and property. For example, a recent routine examination of a main steam line of a power plant revealed a 1 in. deep crack around the circumference of a $1^3/_4$ in. thick valve-to-pipe joint. This crack, illustrated in Fig. 1, is in the heat-affected zone of the valve, parallel to and approximately $^3/_{32}$ in. away from the weld metal. Examination under the microscope established that this cracking occurred in a severely graphitized zone which is shown in Fig. 2. Further embrittlement and propagation of the crack might have resulted in a very serious failure in the main steam line. This valve has been replaced to remove this hazardous condition.

Graphitization is associated primarily with carbon steels in long-time service above 800 F and carbon-molybdenum steels above 900 F. Rolled, forged or cast materials prepared by a high-aluminum deoxidation practice (over $1^1/_2$ lb Al per ton of steel) usually are considered highly susceptible to graphitization. The low-aluminum deoxidized grades (less than $^1/_2$ lb Al per ton of steel) are considered fairly resistant to serious graphitization, although they are not always completely immune. In fact, a recent investigation of a coarse-grained, silicon-killed steel used in a petroleum refinery installation showed heavy graphitization. In a steam power system serious graphitization in a silicon-killed steel so far has been found only in one installation. Thus, it is advisable to examine periodically silicon-killed steel piping.

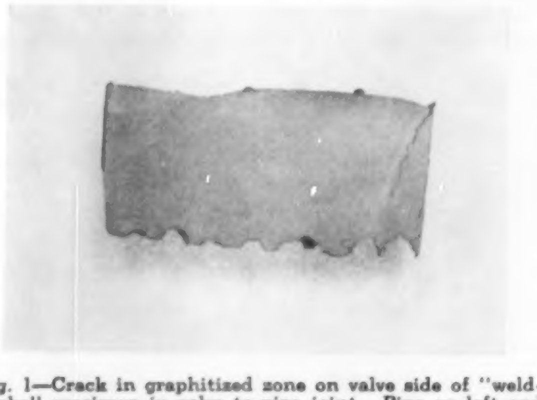


Fig. 1—Crack in graphitized zone on valve side of "weld-probe" specimen in valve-to-pipe joint. Pipe on left and valve on right. (Because of dimensions of valve, the specimen was removed by drilling out)

Thus far $^1/_2$ Cr-$^1/_2$ Mo materials have shown resistance to graphitization in service up to at least 950 F. Similarly, the 1 Cr-$^1/_2$ Mo and $1^1/_4$ Cr-$^1/_2$ Mo grades appear to be resistant up to about 1050 F, although at these temperature levels very limited service data are available to date.

Rolled and forged carbon, carbon-moly and $^1/_2$ Cr-$^1/_2$ Mo steels, from which pipe for steam power systems is fabricated, are now made by the steel mill with a deoxidation practice which limits the maximum permissible aluminum addition to $^1/_2$ lb Al per ton of steel.

Cast steels, as used in valve bodies of carbon and carbon-moly steels, generally are made by a melting practice with 2 lb or more aluminum per ton of steel. The main reason for this is that under ordinary foundry conditions this amount of aluminum is necessary to prevent gas formation in the molds. Although a few foundries have been able to limit the aluminum addition to $^1/_2$ lb Al per ton of steel, the resulting castings

Fig. 3—"Weld-prober" saw in operation removing boat-shaped specimen from pipe-to-valve joint

Fig. 4—Appearance of piping after removal of boat-shaped weld-probe specimen from pipe-to-valve and pipe-to-saddle joints

may be considerably more expensive. Since the addition of $1^1/_4$ per cent chromium and $^1/_2$ per cent molybdenum is likely to inhibit serious graphitization, it is usually economical to specify chrome-moly alloy valve materials.

Since castings, as a general rule, are likely to contain more carbon and aluminum than the corresponding grades of wrought or forged piping materials, the periodic inspection of carbon and carbon-moly valve materials is particularly important.

Metallurgical Considerations

Graphite is free carbon which has little strength, very low ductility and very low resistance to mechanical or thermal fatigue or shock. The physical metallurgist considers its formation as a nucleation and growth process which takes place on long-time exposure at temperatures above 800 F. Graphitization is the result of the diffusion and coalescence of atomic carbon in solution in the steel matrix and the decomposition and diffusion of iron carbide (cementite) into ferrite and free carbon and the subsequent diffusion and coalescence of the latter.

When the graphite occurs in form of nodules distributed at random throughout the steel matrix, its effect upon the mechanical properties of the steel is rather insignificant. However, where the graphite segregates in clusters of nodules along zones or forms continuous chains, the mechanical properties in the affected area may be considerably or even seriously reduced.

A narrow band of particularly unstable carbide and ferrite supersaturated with carbon tends to occur at the extremity of the heat-affected zone in the region where the temperatures resulting from the welding operation reach approximately 1325 to 1425 F for a very short time. Subsequent prolonged service above 800 F may cause particularly severe graphitization in this zone, usually about $^1/_{16}$ to $^1/_8$ in. from the weld.

The degree of graphitization depends primarily upon the composition and thermal history of the steel. For the same type of steel, an increase in the carbon content would tend to increase the amount of graphite that may form.

Alloying or residual elements, which tend to form carbide particles, inhibit graphitization. Thus, chromium, molybdenum, manganese and vanadium are beneficial. If present in a sufficiently large quantity, these elements may prevent graphitization. However, some of these elements may be undesirable because of their effects upon the welding characteristics of the steel.

Sampling

Because of the severe consequences of failures in steam power systems, many power companies have in the past checked, and are periodically checking, the condition of welded joints in pipe and valve materials susceptible to graphitization.

The method most widely used consists of removing boat-shaped slices from welded joints by means of the so-called "weld-prober," illustrated in Fig. 3. The slice is taken across the weld and should include at least $^1/_2$ to 1 in. of base metal at each side of the weld. Typical examples are illustrated in Fig. 4. When properly prepared, the weld-probe slice provides sufficient material for a metallographic examination and one bend test, Fig. 5. Pipe or valve sections of such dimensions as to make attachment of the weld-prober impossible may

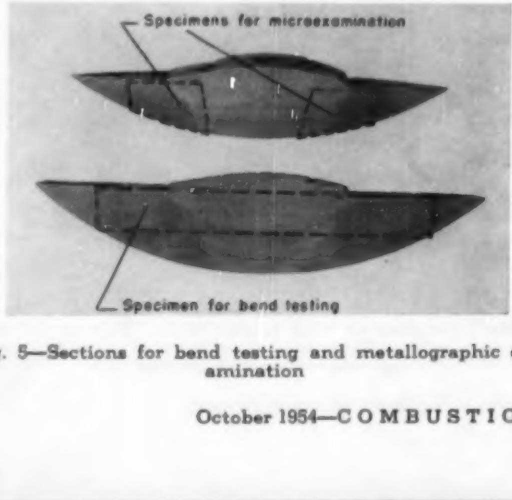


Fig. 5—Sections for bend testing and metallographic examination

require special sectioning procedures, as trepanning or drilling (see Fig. 1).

Upon removal of the slice from the pipe, the cavity is filled by arc welding, Fig. 6. This is often followed by a metallurgical heat treatment, usually at stress-relieving temperatures. Where rehabilitation of the piping system is contemplated, the heat treatment may be omitted or deferred until the weld-probe specimen has been examined. For example, if graphitization is found to be sufficiently severe to necessitate immediate rehabilitation of the affected joints, the final metallurgical heat treatment would also place the joint into the proper stress-relieved condition, as required by the various Codes.

For economic reasons, only one specimen is ordinarily removed from the weld joint. However, since the amount and type of graphitization may vary around the circumference of the pipe joint, the removal of two or three specimens is advisable—particularly where moderate to severe graphitization is suspected. In particular, in cast valve steels where deoxidation was made in the runner box, the aluminum distribution tends to be non-uniform. The resulting differences in the stability of the metallurgical structure may cause a considerable variation in the "degree" of graphitization.

Although it may often be sufficient to examine only one end of a pipe, differences in the stress, welding and post-heating conditions may have resulted in different

Fig. 6—Rewelded area of sampled cap-to-header joint in steam header. Upper, with preheating coils and deposit of initial root pass; lower, completed weld (which has been stress relieved)

"degrees" of graphitization at each pipe end, so that sampling of both ends is advisable. On cast valve steels, it is particularly desirable to examine both ends because of the greater possible variation in the composition of the material.

Grading Graphitization

Since the degree of severity, (i.e., the level of safety of each joint in a steam power system), depends upon the form, shape and distribution of the graphite particles, a relative classification is not readily accomplished. Also, there is no sharp delineation between "severe" and "moderate" graphitization.

The photomicrographs and bend tests obtained from a weld-probe specimen leave room for considerable latitude of interpretation. Careful analysis of such additional operational factors as temperature and pressure cycling, thermal or mechanical fatigue and shock, external loading, section thickness, etc., is also necessary. When of significant magnitude, these factors may contribute to a reduced level of safety of mild or moderately graphitized piping.

On the basis of the 10 years of research in the laboratories of the Grinnell Company, a grading system of graphitized zones has been established which is illustrated in Fig. 7.

The microstructures shown in Fig. 7 generally correspond to the following bend angles (test strips bent to the point where a $^1/_{16}$ in. long crack is first observed in the heat-affected zone):

Graphite Observed in Microstructure	Bend Angle
Mild	Over 90°
Moderate	45–90°
Heavy	30–45°
Severe	15–30°
Extremely severe (dangerous)	Below 15°

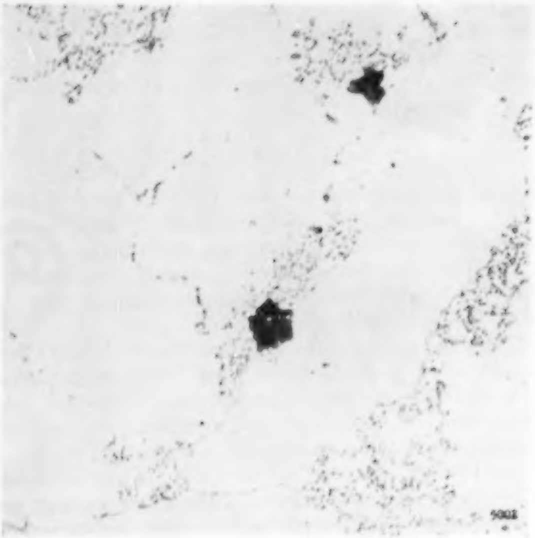
Obviously, the "degree" of graphitization may fall between these gradings.

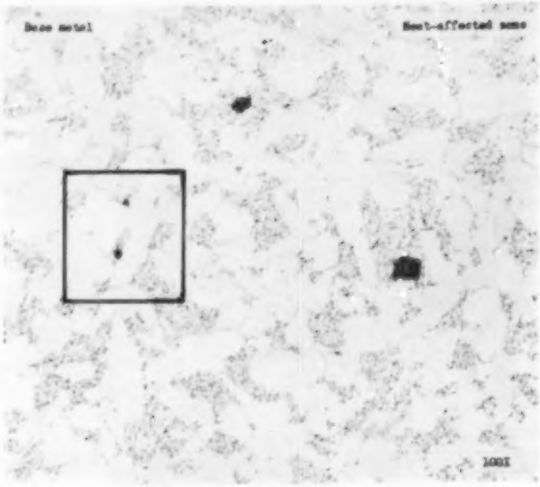
Rehabilitation

Where significant quantities of graphite have been found in the heat-affected zone in piping or valve materials to warrant concern, several procedures have been employed to restore the steam power system to a safer operating condition. These are:

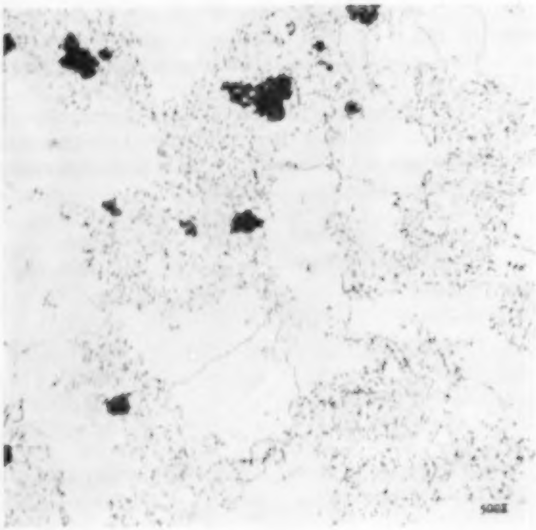
1. Solution heat treatment.
2. Removal of graphitized area in the heat-affected zone by (*a*) partial or (*b*) complete grooving out and rewelding.
3. Replacement of graphitized pipe or valve sections.

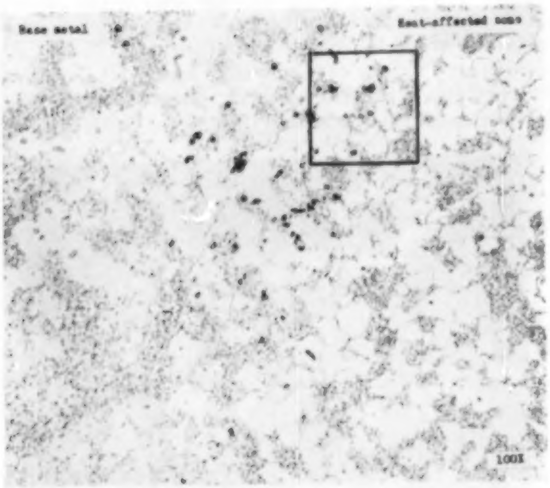
The choice of the proper procedure depends primarily upon the degree of graphitization, the estimated future life and operating conditions of the particular power system and certain economic factors. Sometimes moderately or even heavily graphitized pipe or valve joints which do not show cracking are temporarily rehabilitated by the solution heat treatment until the next shutdown of the steam power system, or until replacement pipe or valve sections can be obtained. It is important to



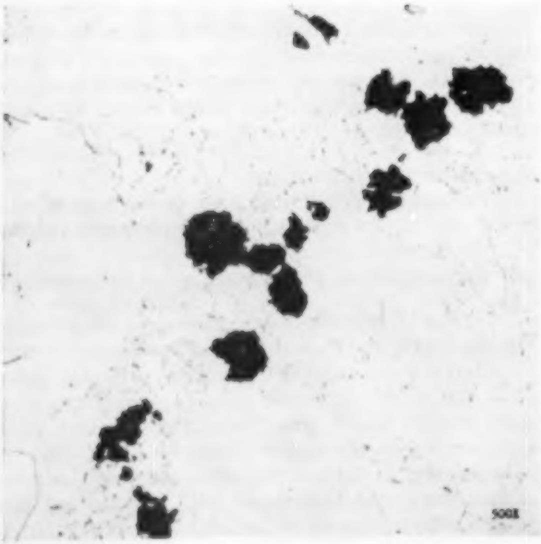


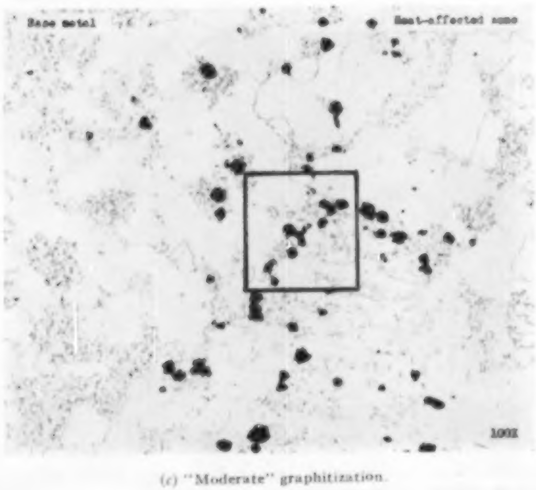
(a) "Very mild" graphitization.





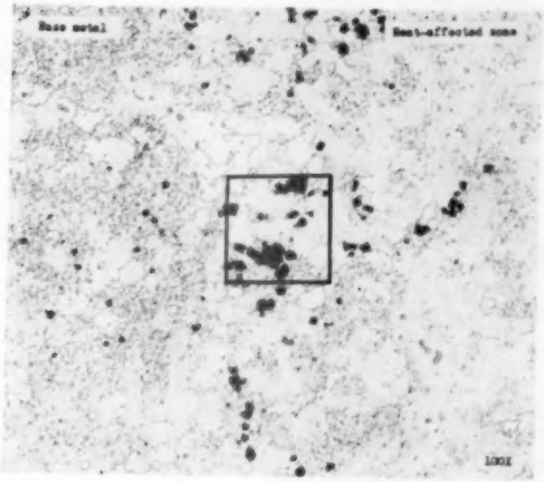
(b) "Mild" graphitization.



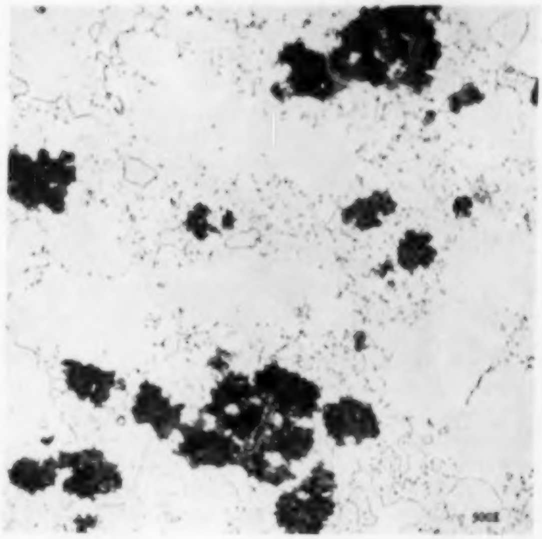


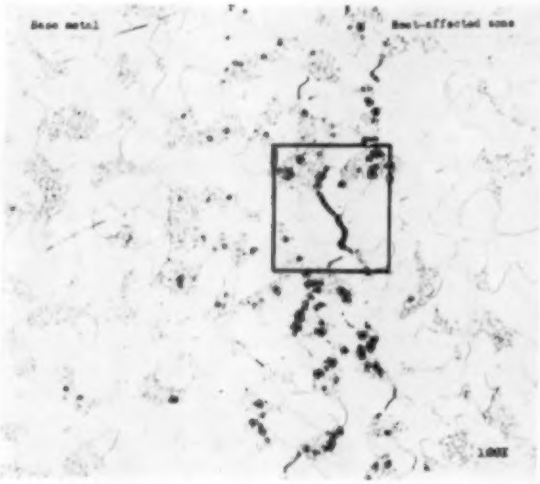
(c) "Moderate" graphitization.

Fig. 7—Microstructures at 100 and 500 diameters

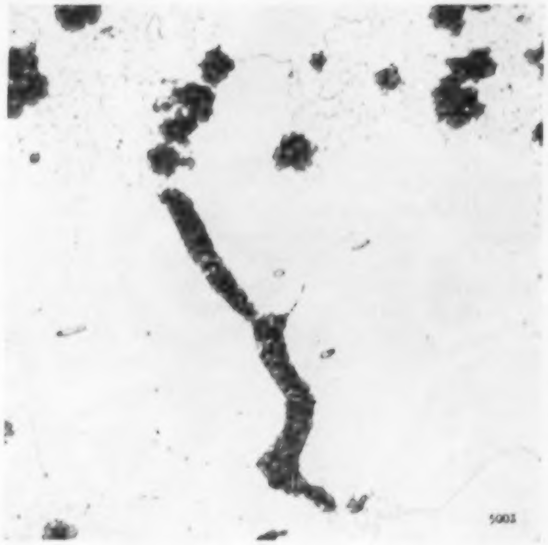


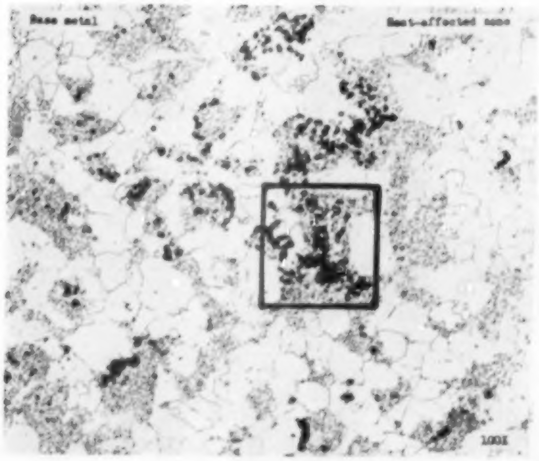
(d) "Heavy" graphitization.



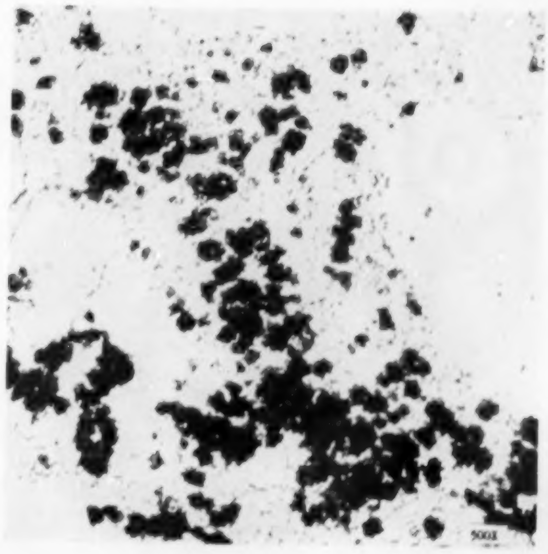


(e) "Severe" graphitization.





(f) "Severe" graphitization.



illustrating various degrees of graphitization

realize that both the solution heat treatment and the rewelding procedure serve only as temporary cures.

The continuous use of materials susceptible to graphitization should be accompanied by periodic examination of weld-probe specimens to study the progress of graphitization. The results of such periodic studies also assist in the selection of a suitable rehabilitation procedure.

Solution Heat Treatment

The solution heat treatment consists of heating the graphitized area to above the upper critical (transformation) temperature of the steel. At these temperatures the "ferritic" steel has transformed into an "austenitic" steel in which the graphite will dissolve. Upon subsequent cooling, the carbon will again be in "solution" or will form cementite particles. A commercial solution heat treatment consists of heating for two to four hours at temperatures between 1700 and 1750 F, depending upon the type of steel and the degree of graphitization. This is followed by controlled cooling to 1000 F at a rate of 300 to 400 deg F per hr.

The major advantage of this procedure is that it is less costly than rewelding or the replacement of pipe or valve sections. However, where long operating periods of five, ten or even more years are involved, the solution heat treatment provides, at best, only a temporary cure. It is generally accepted that graphite will re-form more rapidly and in less time in the solution heat-treated, heat-affected zone than it did in the original stress-relieved weld. It is also believed that the solution of graphite during the solution heat treatment leaves small voids in the steel matrix. These voids continue to act as local stress raisers so that the solution heat treatment does not improve materially the ductility and toughness over that of the previously graphitized area. Thus, subsequent regraphitization during service is likely to further weaken the material. For these reasons the solution heat treatment is now rarely, if ever, recommended.

One large utility company, having first solution heat treated one steam power system, decided subsequently to cut out all welds and heat-affected areas and reweld the entire system. Rewelding in the first place would have been considerably less costly.

Rewelding of Graphitized Area

In this procedure the graphitized area is first removed by flame or arc grooving and/or grinding and is rewelded subsequently. A stress-relieving heat treatment should follow the welding operation.

In the case of moderate graphitization, partial removal of the graphitized area may be adequate. The groove is cut to about $^1/_{16}$ in. from the backing ring on the inside diameter of the pipe or valve. Where graphitization has occurred only on one side of the weld, as may be the case in the valve side of pipe-to-valve joints, the procedure illustrated in Fig. 8 should be followed. Where graphitization has occurred on both sides of the weld, the recommended procedure is illustrated in Fig. 9. The new groove is approximately $^1/_3$ to $^1/_2$ wider than the original groove.

The advantage of this procedure is that fit-up, groove protection and back-up are not required. Of course, proper supporting of the piping is essential in order to prevent cracking in the weld area and not disturb the cold spring (prestress) in the pipe line at room temperature. It must be realized that a small zone of graphitized steel remains at the root of the new weld deposit.

Where the degree of graphitization has been sufficiently heavy to reduce seriously the ductility and toughness in the graphitized area causing cracking to occur in bend specimens at an angle of less than 45 deg, it may be advisable to remove completely the heat-affected and weld areas. The cut ends should then be pulled together, fitted-up and rewelded as illustrated in Fig. 10. In rigid systems it may be desirable to build up the groove faces with weld metal (sometimes called "buttering") and grind to obtain a standard edge preparation prior to the final welding operation of the two ends.

Where necessary, suitable pipe sections should be inserted, preferably of $^1/_2$ Cr-$^1/_2$ Mo, 1 Cr-$^1/_2$ Mo or $1^1/_4$ Cr-$^1/_2$ Mo steel to replace one or several removed sections, as illustrated in Fig. 11. Generally, the $1^1/_4$ Cr-$^1/_2$ Mo grades are most readily available.

In due time graphitization may reoccur in the new heat-affected zones adjacent to the weld. Depending upon the materials involved and the postheating cycle, the rate of graphitization in the new heat-affected zones may be reduced considerably. If the estimated safe operating life exceeds the planned operating life of the steam power system, the rewelding procedure may well be the most economical.

Replacement of Pipe or Valve Sections

In pipe or valve materials which are very susceptible to graphitization and which show graphite in the pipe

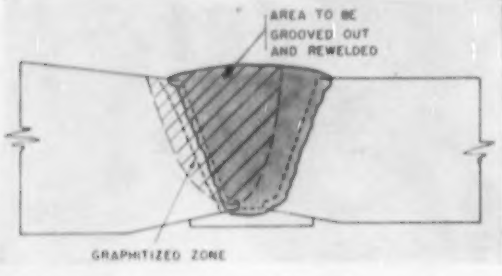


Fig. 8—Sketch illustrating procedure for partial grooving out and rewelding of joint with graphitization on one side of the weld

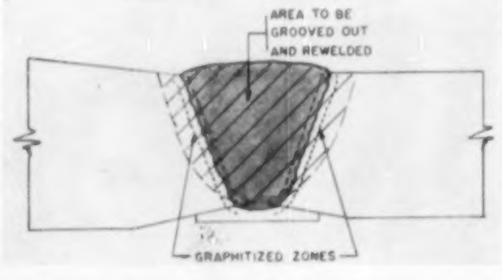


Fig. 9—Sketch illustrating procedure for partial grooving out and rewelding of joint with graphitization on both sides of the weld

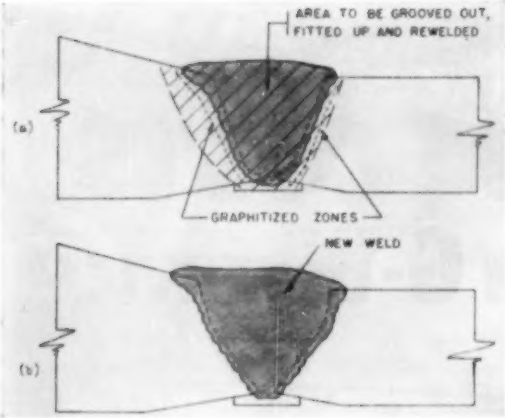


Fig. 10—Sketch illustrating procedure for complete (*a*) grooving out and (*b*) rewelding of joint with graphitization on both sides of the weld

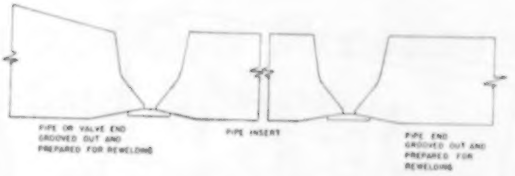


Fig. 11—Sketch illustrating inserting of pipe section to compensate for several weld joints completely grooved out, pulled together, fitted-up and rewelded

or valve metal as well as serious graphitization in the heat-affected zone, it may be advisable to replace completely the graphitized components. Bend specimens which fail at an angle of less than 15 deg usually indicate that the degree of graphitization is extremely severe.

Where pipes and valves are replaced, the use of $^1/_2$ Cr-$^1/_2$ Mo, 1 Cr-$^1/_2$ Mo or $1^1/_4$ Cr-$^1/_2$ Mo materials should be considered. The replaced sections are not likely to give further graphitization troubles. Little or no further sampling is required. Moreover, improved design and fabrication practice of present-day piping and valve systems results in lower pressure drops and higher quality joints so that higher efficiencies and lower maintenance can be obtained.

Postheat Treatment

After the welds have been completed, a metallurgical heat treatment is generally employed which consists of heating the weld area to 1300 to 1350 F for four hours. This heat treatment retards future graphitization. Reoccurrence of graphite in carbon-moly pipe welds when heat treated in this manner, if at all, usually is in the widely scattered nodular form. Subsequent heavy graphite concentrations in the heat-affected zone are rarely found.

Recommending Rehabilitation

Rehabilitation by (1) removal of graphitized area in heat-affected zone by (*a*) partial or (*b*) complete grooving out and rewelding or (2) the replacement of graphitized pipe or valve sections is usually advisable where the degree of graphitization is found to be heavy, severe or extremely severe. Because the most suitable method varies with each particular steam power system, a definite recommendation cannot be made on the basis of a laboratory examination alone. The proper method can be determined only after a careful review and evaluation of the economic and operational factors such as operating and peak temperatures and pressures, cycling, thermal or mechanical fatigue and shock conditions, expected service life, retirement of the particular steam power unit, etc. The overall condition of the whole steam power unit must be considered also. If many joints show "heavy" graphitization, it may be advisable to cut out completely the respective weld joints and heat-affected zones as illustrated in Fig. 11. Where only one joint shows "heavy" graphitization, partial grooving out and rewelding may be sufficient.

For the purpose of illustration only, example recommendations are given below for a particular steam power system. The following operational characteristics are assumed for this hypothetical installation:

Total operation	100,000 hr
Expected future operation	150,000 hr
Operating temperature	890–915 F.
Operating pressure	970–980 psig
Shutdowns	2 per year
Conditions for severe thermal shock	Negligible
Exposure to mechanical vibrations	Negligible
Piping material	Carbon-moly (ASTM A206)
Deoxidation practice	2 lb aluminum per ton of steel
Pipe size	12 in. nom. ($12^3/_4$ in. OD)
Wall thickness	1.3 in. (schedule 160)

The following recommendations might be made:

Degree of Graphitization	Recommended Rehabilitation
None	Take another weld-probe specimen after 20,000–30,000 hr of service.
Mild	Take another weld-probe specimen after 8000–10,000 hr of service.
Moderate	Gouge out (partially) heat-affected zone and reweld.
Heavy	Cut out (completely) heat-affected zone and reweld.
Severe	Replace respective piping or valve materials at next scheduled shutdown. Check affected materials for cracks.
Extremely severe	Present condition of material extremely hazardous. Check for cracks, make immediate repairs and replace materials as soon as replacement sections can be obtained.

Where a system is subject to severe thermal or mechanical shock, the above recommendations might include radiographic and magnetic particle inspection of the steam power system.

*Forced Outage Rates of High Pressure Steam Turbines and Boilers**

By AIEE Joint Subcommittee on Application of Probability Methods to Power System Problems

Introduction

This report is a continuation of an earlier study[1] of forced outage data collected by committees of the Edison Electric Institute. The present report is confined to horizontal steam turbine-generators operating at pressures of 700 psi or greater and rated at or over 20,000 kw condensing or 10,000 kw superposed, and to boilers with continuous rated capacity of 200,000 lb per hr or more and with outlet pressures of 700 psi or greater.

The primary objective of this study is to obtain the forced outage rate of the above class of equipment for use by operating companies in determining their reserve requirements by probability methods.

The data collected by the Prime Movers Committee of the Edison Electric Institute for 1950, 1951 and 1952 was analyzed by Mr. Veazey M. Cook of the System Engineering Department of Consolidated Edison Company of New York, Inc. The results are included in this paper as a progress report.

Outage Definitions

Outages as classified in this report include all those, regardless of length, which existed during the heavy load portions of the day. Each day on which such outage existed is counted as a full day of outage. Outages confined to light load hours of the day are disregarded. The heavy load period of the day may vary somewhat from system to system, but approximately it is the period from 7:00 a.m. to 10:00 p.m.

Instructions on classification of outages as issued to the operating companies are included herein as Appendix A for turbines and Appendix B for boilers.

Outage Experience Tables

Tables I and II for turbines and III and IV for boilers show the performance or status of turbines and boilers during the three-year period 1950–1952, both for all days and for weekdays excluding Saturdays, Sundays and major holidays.

The availability factor for turbines of all pressures is shown by Table I as 92.61 per cent which is the sum of the percentage for unit-days available but not operated (1.38%) and the percentage of unit-days operated (91.23%), both of which are expressed as a percentage of total unit-days installed. The availability factor for boilers on the same basis is shown by Table III as 90.90 per cent.

Forced Outage Rates for Turbines

The forced outage rates for turbines are shown in Table V and are summarized for each annual survey as follows:

	Forced Outage Rate, Per Cent 1950	1951	1952	1950–52
Pressures less than 1000 psi	1.42	0.66	0.43	0.81
Pressures from 1000 to 1350 psi	1.59	0.81	0.82	1.07
Pressures more than 1350 psi	*	*	*	0.58
All pressures	1.40	0.71	0.59	0.88

* The values for pressures more than 1350 psi are not significant annually due to the small number of turbines reported for this class.

[1] "Outage Rates of Steam Turbines and Boilers and of Hydro Units," AIEE Technical Paper 49-112, January 1949; same *Transactions* AIEE, Volume 68, 1949.

* Presented at the AIEE General Meeting, Chicago, Ill., Oct. 11–15, 1954.

TABLE I—SUMMARY PERFORMANCE OF TURBINE-GENERATOR UNITS OPERATING AT 700 PSI OR GREATER AND RATED AT OR OVER 20,000 KW CONDENSING OR 10,000 KW SUPERPOSED; YEARS 1950, 1951, 1952, ALL DAYS

	Less Than 1000 Psi			From 1000 to 1350 Psi			More Than 1350 Psi			All Pressures		
	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of turbine-generators reported on	530†			286†			77†			893†		
On forced outage, due to unit	1 670	0.87	0.96	1 135	1.10	1.21	160	0.58	0.65	2 965	0.92	1.01
On forced outage, due to other cause	934	0.49	0.53	695	0.68	0.74	277	1.01	1.14	1 906	0.60	0.65
Total forced outage	2 604	1.36	1.49	1 830	1.78	1.95	437	1.59	1.79	4 871	1.52	1.66
Week day outage transferable to week-end	445	0.23	0.25	274	0.27	0.29	121	0.44	0.50	840	0.26	0.29
Week-end outage*	569	0.30	0.33	417	0.40	0.45	329	1.20	1.35	1 315	0.41	0.45
On scheduled outage, due to unit	7 891	4.13	4.51	4 503	4.38	4.80	1 497	5.46	6.14	13 891	4.32	4.74
On scheduled outage, due to other cause	1 503	0.79	0.86	827	0.80	0.88	506	1.84	2.08	2 835	0.88	0.97
Total scheduled outage	9 394	4.92	5.37	5 330	5.18	5.68	2 003	7.30	8.22	16 727	5.20	5.71
Available but not operated	2 982	1.56	1.70	1 267	1.23	1.35	187	0.68	0.77	4 436	1.38	1.51
In operation	175 004	91.63	100.00	93 805	91.14	100.00	24 366	88.79	100.00	293 175	91.23	100.00
Total Unit-Days Installed	190 998	100.00		102 923	100.00		27 443	100.00		321 364	100.00	
Not Installed	2 645			1 582			700			4 927		
Total All Unit-Days	193 643			104 505			28 143			326 291		

Note: Partial turbine-generator outages are neglected. Table covers status during heavy load period of day only. * Classification not included in 1950. † Unit-Years.

TABLE II—SUMMARY-PERFORMANCE OF TURBINE-GENERATOR UNITS OPERATING AT 700 PSI OR GREATER AND RATED AT OR OVER 20,000 KW CONDENSING OR 10,000 KW SUPERPOSED; YEARS 1950, 1951, 1952, WEEK DAYS ONLY

	Less Than 1000 Psi			From 1000 to 1350 Psi			More Than 1350 Psi			All Pressures		
	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of turbine-generators reported on	530†			286†			77†			893†		
On forced outage, due to unit	1 020	0.77	0.82	712	1.00	1.07	104	0.55	0.60	1 836	0.83	0.89
On forced outage, due to other cause	481	0.36	0.39	366	0.52	0.55	159	0.84	0.91	1 006	0.45	0.48
Total forced outage	1 501	1.13	1.21	1 078	1.52	1.62	263	1.39	1.51	2 842	1.28	1.37
Weekday outage transferable to week-end	167	0.13	0.14	93	0.13	0.14	30	0.16	0.17	290	0.13	0.14
Week-End outage*	47	0.04	0.04	18	0.03	0.03	16	0.08	0.09	81	0.04	0.04
On scheduled outage, due to unit	5 272	4.00	4.27	2 988	4.20	4.51	965	5.09	5.53	9 225	4.16	4.45
On scheduled outage, due to other cause	718	0.54	0.58	418	0.59	0.63	227	1.20	1.30	1 363	0.61	0.66
Total scheduled outage	5 990	4.54	4.85	3 406	4.79	5.14	1 192	6.29	6.83	10 588	4.77	5.11
Available but not operated	720	0.55	0.58	181	0.25	0.27	8	0.04	0.05	909	0.41	0.44
In operation	123 501	93.61	100.00	66 319	93.28	100.00	17 447	92.04	100.00	207 267	93.37	100.00
TOTAL UNIT-DAYS INSTALLED	131 925	100.00		71 095	100.00		18 956	100.00		221 976	100.00	
Not Installed	1 827			1 092			486			3 405		
TOTAL ALL UNIT-DAYS	133 953			72 187			19 442			225 382		

NOTE: Partial turbine-generator outages are neglected. Table covers status during heavy load period of day only. * Classification not included in 1950
† Unit-Years.

The above outage rates are based on outages chargeable to the turbine alone and are adjusted for excess of weekend outages.

Forced Outage Rates for Boilers

The forced outage rates for boilers are shown in Table VI and are summarized for each annual survey as follows:

	Forced Outage Rate, Per Cent 1950	1951	1952	1950–52
Pressures less than 1000 psi	0.89	0.55	0.78	0.74
Pressures from 1000 to 1350 psi	1.70	1.30	1.34	1.45
Pressures more than 1350 psi	*	*	*	0.75
All pressures	1.17	0.78	0.93	0.95

* The values for pressures more than 1350 psi are not significant annually due to the small number of boilers reported for this class.

The above outage rates are based on outages chargeable to the boiler alone and are adjusted for excess of week-end outages.

Collection of Data

Data was collected by means of a standard questionnaire explained in Appendix A and B below.

Appendix A

Edison Electric Institute Committee on Prime Movers—Subcommittee on Turbines, Explanatory Notes to Accompany Graphic Questionnaire, "System Summary—Daily Record of Steam Turbine Operation and Outage."

Purpose: This questionnaire is distributed to obtain data needed for studies of reserve requirements.

Sample Form: On the accompanying sample chart six months' experience data for a system of five units have been entered to illustrate the use of the form. Systems reporting on 1 to 3 units can put 12 months on one page; on 4 to 6 units, 6 months on one page, on 7 to 9 units, 4 months on one page, etc.

Unit Identification, Etc.: The descriptive data for the individual units are the same as that requested on the regular turbine subcommittee questionnaire.

Reported Outage: Any outage, regardless of length, that occurred or existed during the peak portion of the day is to be counted as one full day of outage, while an outage which was confined to off-peak hours of the day should be disregarded. Cases of successive nonoverlapping out-

TABLE III—SUMMARY-PERFORMANCE OF BOILERS WITH CONTINUOUS RATED CAPACITY OF 200,000 LB PER HR OR MORE AND WITH OUTLET PRESSURE OF 700 PSI OR GREATER; YEARS 1950, 1951, 1952, ALL DAYS

		Less Than 1000 Psi			From 1000 to 1350 Psi			More Than 1350 Psi			All Pressures		
		Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of boilers reported on		654*			372*			194*			1 220*		
On forced outage, due to unit	Full	1 478	0.63	0.69	1 548	1.15	1.31	462	0.66	0.75	3 488	0.79	0.89
	Partial	750	0.32	0.35	857	0.64	0.73	293	0.42	0.48	1 900	0.43	0.48
On forced outage, due to other cause	Full	593	0.25	0.28	528	0.39	0.45	241	0.35	0.39	1 362	0.31	0.34
	Partial	35	0.02	0.02	24	0.02	0.02	9	0.01	0.01	68	0.02	0.02
On maintenance outage, due to unit	Full	3 442	1.46	1.60	3 420	2.54	2.91	2 444	3.51	3.98	9 306	2.11	2.36
	Partial	301	0.13	0.14	375	0.28	0.32	59	0.08	0.10	735	0.17	0.19
On maintenance outage, due to other cause	Full	978	0.41	0.45	590	0.44	0.50	482	0.69	0.79	2 050	0.47	0.52
	Partial	13	0.01	0.01	25	0.02	0.02	0	0.00	0.00	38	0.01	0.01
On overhaul outage, due to unit	Full	9 866	4.18	4.60	5 988	4.45	5.09	3 073	4.41	5.01	18 927	4.30	4.81
	Partial	5	—	—	5	—	—	0	0.00	0.00	10	—	—
On overhaul outage, due to other cause	Full	1 303	0.55	0.61	382	0.28	0.32	398	0.57	0.65	2 083	0.47	0.53
	Partial	55	0.02	0.03	8	0.01	0.01	1	—	—	64	0.02	0.02
Available but not operated (excludes partial)		2 783	1.18	1.30	3 170	2.35	2.69	882	1.27	1.44	6 835	1.55	1.74
In operation (excludes partial operation)		214 267	90.84	100.00	117 719	87.43	100.00	61 371	88.03	100.00	393 357	89.35	100.00
TOTAL UNIT-DAYS INSTALLED		235 869	100.00		134 639	100.00		69 715	100.00		440 223	100.00	
Not installed		3 079			1 284			1 187			5 550		
TOTAL ALL UNIT-DAYS		238 948			135 923			70 902			445 773		

NOTE: Table covers status during heavy load period of day only. * Unit-Years.

TABLE IV—SUMMARY-PERFORMANCE OF BOILERS WITH CONTINUOUS RATED CAPACITY OF 200,000 LB PER HR OR MORE AND WITH OUTLET PRESSURE OF 700 PSI OR GREATER; YEARS 1950, 1951, 1952, WEEKDAYS ONLY

		Less Than 1000 Psi			From 1000 to 1350 Psi			More Than 1350 Psi			All Pressures		
		Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operatin_
Number of boilers reported on		654*			372*			194*			1 220*		
On forced outage, due to unit	Full	918	0.56	0.61	943	1.01	1.12	261	0.54	0.60	2 122	0.70	0.76
	Partial	417	0.26	0.28	558	0.60	0.66	116	0.24	0.27	1 091	0.36	0.39
On forced outage, due to other cause	Full	331	0.20	0.22	334	0.36	0.40	149	0.31	0.34	814	0.27	0.29
	Partial	22	0.01	0.01	18	0.02	0.02	4	0.01	0.01	44	0.01	0.02
On maintenance outage, due to unit	Full	1 450	0.89	0.96	1 455	1.57	1.73	1 090	2.26	2.50	3 995	1.32	1.43
	Partial	202	0.13	0.13	247	0.27	0.29	37	0.08	0.08	486	0.16	0.17
On maintenance outage, due to other cause	Full	349	0.22	0.23	255	0.27	0.30	216	0.45	0.50	820	0.27	0.29
	Partial	4	—	—	22	0.02	0.03	0	0.00	0.00	26	0.01	0.01
On overhaul outage, due to unit	Full	6 690	4.11	4.43	4 049	4.35	4.82	2 072	4.30	4.75	12 811	4.21	4.60
	Partial	2	—	—	2	—	—	0	0.00	0.00	4	—	—
On overhaul outage, due to other cause	Full	786	0.48	0.52	227	0.24	0.27	261	0.54	0.60	1 274	0.42	0.46
	Partial	37	0.02	0.02	6	0.01	0.01	1	—	—	44	0.01	0.02
Available but not operated (excludes partial)		603	0.37	0.40	836	0.90	1.00	325	0.68	0.74	1 764	0.58	0.63
In operation (excludes partial operation)		151 111	92.75	100.00	84 051	90.38	100.00	43 628	90.59	100.00	278 790	91.68	100.00
Total Unit-Days Installed		162 922	100.00		93 003	100.00		48 160	100.00		304 085	100.00	
Not installed		2 124			884			820			3 828		
Total All Unit-Days		165 046			93 887			48 980			307 913		

Note: Table covers status during heavy load period of day only. * Unit-years.

ages on the same day will have to be covered by remarks on the reverse side of the sheet. Outage days should be classified as described below.

Reduced Capacity Operation: Cases of temporary operation at materially reduced capacity will have to be handled as remarks, giving capacity loss and dates. Remarks should be written on the reverse side of the form sheet.

Transferable Outage: Occasionally, on systems having a temporary superabundance of reserve capacity, units may have been out during the peak hours of weekdays for work which if the reserve had been normal could and would have been transferred and confined to off-peak hours of the day or to a nearby week-end or holiday period. These outages are classed as transferable.

Scheduled Outage: A scheduled outage is one widely controllable as to time of occurrence so that it might have been or was postponed from one season to another or even to another year. Such outages will usually have been planned months in advance. Annual overhaul is a typical scheduled outage. Scheduled outages are further classified as due to the unit (turbo-generator, condenser and own auxiliaries): or as due to other causes such as: boiler, station or system rearrangement; or reconstruction of a unit to increase capacity, change frequency, etc. as contrasted with reconstruction because of an excessive failure rate.

Forced Outage: A forced outage is one due to causes requiring that the unit be taken out of service at once or as soon thereafter as possible. This includes cases where the cause of the outage is of such nature that the unit is not removed from service until the off-peak period of the same day or following week-end and where the time for repairs extends beyond the off-peak period, in which case the outage is classified as forced during the time extended beyond the off-peak period. Outages on week-ends and holidays will be given separate treatment in the analysis of the returns, so that forced outages which were postponed to such days should be reported in the same way as others. Forced outages are further

TABLE V—DURATION AND FREQUENCY OF OCCURRENCE OF TURBINE-GENERATOR FORCED OUTAGES TERMINATING DURING THE YEARS 1950, 1951 AND 1952 FOR UNITS OPERATING AT PRESSURES OF 700 PSI OR GREATER AND RATED AT OR OVER 20,000 KW CONDENSING OR 10,000 KW SUPERPOSED

Outage Duration in Days	Less Than 1000 Psi Actual	Less Than 1000 Psi Adjusted*	From 1000 to 1350 Psi Actual	From 1000 to 1350 Psi Adjusted*	More Than 1350 Psi Actual	More Than 1350 Psi Adjusted*	All Pressures Actual	All Pressures Adjusted*
1	209	112	126	88	24	19	359	219
2	69	33	54	37	6	3	129	73
3	26	5	23	8	4	2	53	15
4	12	12	5	5	2	2	19	19
5	6	6	0	0	2	2	8	8
6	2	2	1	1	3	3	6	6
7	3	3	2	2	0	0	5	5
8	1	1	3	3	0	0	4	4
9	1	1	2	2	0	0	3	3
10	1	1	2	2	0	0	3	3
11–15	4	4	3	3	0	0	7	7
16–25	6	6	5	5	1	1	12	12
26–50	5	5	8	8	0	0	13	13
51–100	5	5	4	4	1	1	10	10
101 up	3	3	0	0	0	0	3	3
Total number of occurrences (A)	353	199	238	168	43	33	634	400
Unit days of outage included above (B)	1 672	1 440	1 166	1 049	160	143	2 998	2 632
Unit days of outage prior to period	2	2	31	31	0	0	33	33
Unit days of outage overrunning period	0	0	0	0	0	0	0	0
Unit days of outage in period (C)	1 670	1 438	1 135	1 018	160	143	2 965	2 599
Average duration of one outage: days B/A	4.74	7.24	4.90	6.24	3.72	4.33	4.73	6.58
Unit days of full operation in period	175 004	175 004	93 805	93 805	24 366	24 366	293 175	293 175
Unit days exposed in period (D)	176 674	176 442	94 940	94 823	24 526	24 509	296 140	295 774
Days exposed per outage D/A	500	887	399	564	570	743	467	739
Forced Outage Rate, per cent C/D	0.95	0.81	1.20	1.07	0.65	0.58	1.00	0.88
Number of turbine-gnenerators reported on†	530	530	286	286	77	77	893	893

Note: This table includes only outages chargeable to unit alone. * Adjusted for excess of short outages on week ends. † Unit-Years.

classified as due to the unit (turbo-generator, condenser, and own auxiliaries), or as due to other causes such as boiler or transmission line unavailability, flood, bus failure, etc.

Combined Forced and Scheduled Outage: In certain cases of long forced outage the opportunity may have been utilized to schedule necessary overhaul work at the same time. The total duration of the outage may then have been determined by the overhaul. Since the primary interest of this questionnaire is forced outage, it is requested that in such cases the approximate outage time which would have been required without the overhaul be marked as forced outage and the remainder as scheduled outage.

Days Operated: If on any given day a unit was in service, i.e., actually operated with switches closed to station bus for any length of time, however short, one full day of operation should be counted, unless a reported outage as defined above occurred on the same day.

Days Not Installed: Days prior to initial operation or following retirement of a unit should be marked days not installed. Days on which the generator was left uncoupled for operation as a synchronous condenser should also be marked days not installed.

Days Available but Not Operated: Obviously the days remaining after identifying outage days, days operated and days not installed are days available but not operated.

Treatment of Compound Units: In the case of three-element cross-compound units, if the elements are *regulary* arranged so that the unit can be operated with *any* one element out, the elements should be reported as separate units.

Appendix B

Edison Electric Institute, Committee on Prime Movers—Boiler Subcommittee, Explanatory Notes to Accompany Graphic Questionnaire, "System Summary—Daily Record of Steam Boiler Operation and Outage."

Purpose: This questionnaire is distributed to obtain data desired as a basis for determining reserve requirements, and supplements a similar questionnaire on turbine outage. It is recognized that the greater part of boiler outage time is for preventive maintenance work in anticipation of forced outage, which work can either be evenly distributed in time or scheduled for off-peak seasons; that the amount and frequency of such work will generally be determined by the design features of the boilers and the characteristics of the fuel burned; and that consequently the maintenance requirements must be determined by local experience or by particular analogy. It is also apparent that in some cases the necessary reserve for maintenance will permit absorption of a considerable amount of forced or emergency boiler outage, while in other cases the maintenance schedule is so crowded that any other outages must come out of of additional reserves. Nonetheless it seems desirable to attempt to determine the prospective incidence of forced boiler outage.

Boiler Unit: The boiler unit will be considered to include all components, fittings, piping, ducts and auxiliaries except those used or designed to be used in common with other boilers.

Reported Outages: Any outage, regardless of length, which existed or occurred during the peak load portion of the day should be counted as one full day of outage, while an outage which was confined to off-peak hours of the day should be disregarded. Cases of successive non-overlapping outages on the same day will have to be covered by remarks on the reverse side of the sheet. Outage days should be classified as described below.

Partial Outage: Where outage of some component, such as a mill or a fan, results in reducing capacity by a major fraction, as one-half or one-third, that outage should be reported as a fractional capacity outage in the manner indicated on the form. Cases in which boilers either after or in anticipation of failure were repaired or altered for temporary operation at materially reduced capacity should also be reported as partial outages.

Overhaul Outage: An overhaul outage is one widely controllable as to time of occurrence so that if desired it might have been or was avoided during the peak load

TABLE VI—DURATION AND FREQUENCY OF OCCURRENCE OF BOILER FORCED OUTAGES TERMINATING DURING THE YEARS 1950, 1951 AND 1952 FOR BOILERS WITH CONTINUOUS RATED CAPACITY OF 200,000 LB PER HR OR MORE AND WITH OUTLET PRESSURE OF 700 PSI OR GREATER

	Less Than 1000 Psi		From 1000 to 1350 Psi		More Than 1350 Psi		All Pressures	
Outage Duration in Days	Actual	Adjusted*	Actual	Adjusted*	Actual	Adjusted*	Actual	Adjusted*
1	397	301½	472½	421½	174	102½	1 043½	825½
2	205	142½	214½	164½	77½	45	497	352
3	76	61½	81½	50	20	18	177½	129½
4	39½	39½	43	43	14	14	96½	96½
5	22½	22½	29	29	9	9	60½	60½
6	10½	10½	9	9	5½	5½	25	25
7	5	5	1	1	4½	4½	10½	10½
8	3½	3½	3½	3½	1	1	8	8
9	2	2	3	3	0	0	5	5
10	3	3	6	6	0	0	9	9
11–15	8½	8½	9½	9½	5½	5½	23½	23½
16–25	4½	4½	2½	2½	0	0	7	7
26–50	1½	1½	3	3	0	0	4½	4½
51–100	2	2	1	1	0	0	3	3
101 up	0	0	0	0	0	0	0	0
Total number of occurrences (A)	780½	608	879	746½	311	205	1 970½	1 559½
Unit days of outage included above (B)	1 853	1 589	1 971½	1 726	633½	491	4 458	3 806
Unit days of outage prior to period	0	0	0	0	25	25	25	25
Unit days of outage overrunning period	0	0	0	0	0	0	0	0
Unit days of outage in period (C)	1 853	1 589	1 971½	1 726	608½	466	4 433	3 781
Average duration of one outage: days B/A	2.37	2.61	2.24	2.31	2.04	2.40	2.26	2.44
Unit days of full operation in period	214 267	214 267	117 719	117 719	61 371	61 371	393 357	393 357
Unit days exposed in period (D)	216 120	215 856	119 690½	119 445	61 979½	61 837	397 790	397 138
Days exposed per outage D/A	275	355	136	160	199	302	202	255
FORCED OUTAGE RATE, per cent C/D	0.86	0.74	1.65	1.45	0.98	0.75	1.11	0.95
Number of Boilers Reported on†	654	654	372	372	194	194	1 220	1 220

NOTE: This table includes only outages chargeable to unit alone. One-half of actual partial outage days and one-half of the number of partial outages are included. * Adjusted for excess of short outages on week ends. † Unit Years.

season of the year. Such outages will generally have been scheduled months in advance. Overhaul outages are further classified as due to unit, e.g., for renewal or repair of components or for correction of defects of the boiler itself or of its own auxiliaries; or as due to other causes, such as station rearrangement or alteration to increase capacity or to change the type of combustion equipment, etc.

Maintenance Outage: A maintenance outage is one which cannot be postponed from one season to another but which can be assigned in advance so as to maintain an even or a minimum amount of simultaneous outage, or to utilize week-end time. Maintenance outages are further classified as due to unit or to other cause. A typical maintenance outage due to unit might be renewal of stoker parts or of furnace refractory in anticipation of failure; while one due to other cause might be replacement of a steam header valve beyond the boiler stop valve.

Forced Outage: A forced outage is one due to causes requiring that the unit be taken out of service at once or as soon thereafter as possible. This includes cases where the cause of the outage is of such nature that the unit is not removed from service until the off-peak period of the same day or following week-end and where the time for repairs extends beyond the off-peak period, in which case the outage is classified as forced during the time extended beyond the off-peak period. Forced outages are further classified as due to unit or to other causes. A typical forced outage due to unit might be a tube rupture or the failure of the fan drive. A forced outage due to other cause might result from feed water or from coal failure.

Combined Forced and Overhaul Outage: In certain cases of long forced outage the opportunity may have been utilized to schedule necessary overhaul work at the same time. The total duration of the outage may then have been determined by the overhaul. Since the primary interest of this questionnaire is forced outage, it is requested that in such cases the approximate outage time which would have been required without the overhaul be marked as forced outage and the remainder as overhaul outage.

Days Operated: If on any given day a boiler was burning fuel for any length of time, however short and whether banked or steaming, one full day of operation should be counted unless a reported outage as defined above occurred on the same day.

Days Not Installed: Days prior to inital operation or following retirement of a boiler should be marked days not installed.

Days Available but Not Operated: Obviously the days remaining after identifying outage days, days operated and days not installed are days available but not operated. Days available will include days laid up.

Operating Rate: The average operating rate is equal to the total output in lb of steam divided by the product of hours steaming and the maximum continuous rating in lb of steam per hour. The usual maximum operating rate is equal to the maximum lb of steam per hour at which the boiler is usually operated (in absence of contingencies) divided by the maximum continuous rating in lb of steam per hour.

ASME Fall Meeting Held at Milwaukee

THE Fall Meeting of The American Society of Mechanical Engineers was held at the Hotel Schroeder in Milwaukee on September 8–10. The meeting, which celebrated the 50th anniversary of the ASME Milwaukee Section, featured a wide variety of papers on utilization of lignite and paper-mill waste liquors, reheat turbine controls, package-boiler designs and controls, the supercritical pressure cycle, forced-convection heat transfer and gas-turbine testing. Inspection trips were made to the Oak Creek Power Plant of Wisconsin Electric Power Co., the West Allis Works of Allis-Chalmers Mfg. Co. and to the plant of the Chain Belt Co.

In an address entitled "Champions Are Not Complacent," **Lewis K. Sillcox,** president of ASME, observed that current attacks on learning come from those in America who are afraid of progress and dislike change and novelty. He pointed out that the man of real independence is the "reasonable person, usually the fellow in the middle, attacked by the dogmas of all extremes, but still willing, ready and anxious to fight for his own independence of thought and action, and the Divine right to change his mind for good cause."

M. H. Trytten, director of the Office of Scientific Personnel of the National Research Council, presented the results of a two-year study on Russian engineering education made in conjunction with the Russian Research Institute at Harvard University. The number of higher educational institutions in Russia increased from 750 in 1939 to 900 in 1952, while enrollment increased by 50 per cent to 916,000 in the same period. Engineering graduates in Russia have increased from 29,000 in 1948 to over 50,000 in 1954, which may be compared to about 19,000 in American institutions this year. Apart from numbers of graduates, Dr. Trytten stated that Russian engineering training lasts five to five and one half years, consisting of about 5000 hr of lectures, classroom and laboratory instruction. The curriculum is arranged so that the student spends about 65 per cent of his time on general sciences and general education subjects; about 28 per cent, in narrow specialization; and the remaining 7 per cent in what might be described as political indoctrination subjects.

Lignite Utilization

In a paper entitled "Design and Operational Aspects Regarding Utilization of North Dakota Lignite in Steam Generating Units," **H. R. Cowles** of Otter Tail Power Co. briefly described the latest steam generating units installed in the North Dakota lignite-burning area. He strongly emphasized that there are no mysteries in burning this type of lignite in boiler sizes up to 230,000 lb of steam per hour and that modern boiler techniques have proved adequate when altered in accordance with specific fuel characteristics.

Two pulverized-lignite-fired boilers rated at 230,000 lb per hr have been in operation over two years. Burner flame has been quite stable, and no more than the usual operating difficulties have been experienced. A 250,000 lb-per-hr continuous-discharge spreader-stoker fired unit is now under construction near Mandan, N. D. It is being designed for 975 psig, 905 F. Within the next four or five years it is expected that there will be boilers having capacities of 500,000 to 600,000 lb per hr operating at 1450 psig, 1000 F with reheat to the initial temperature. By 1967 it is probable that boiler-turbine-generator units of 100,000 kw will be using North Dakota lignite as fuel.

Discussing fly-ash reinjection with spreader stokers, Mr. Cowles stated that the reinjection system produces serious problems with questionable benefits. Many lignite ashes have clogging characteristics that must be allowed for in the design of duct work, air heaters and dust collectors. The use of electric vibrators on dust collectors and bypass arrangements to prevent gas temperatures from falling below 350 F in the collectors has proved helpful.

Discussion

Mention was made of the use of the high-set spreader stoker employing turbulent suspension burning for boiler capacities to 300,000 lb of steam per hour and higher. Full rear arch furnaces with a very thin lignite bed on traveling-grate stokers may be used to advantage in designs up to 200,000 lb per hr.

Lignite can be successfully stored in small and large quantities. Through the use of thin strata and proper compacting, piles up to 40 ft in height have been formed. It was mentioned that the U. S. Bureau of Mines had just issued a comprehensive two-volume study (Information Circular 7691-92) entitled "Technology of Lignitic Coals" which includes industrial development possibilities, occurrences and properties, mining practice, combustion and power generation, gasification, hydrogenation and other chemical processing.

Reheat Turbine Overspeed Protection

Overspeed problems created by the accelerating potential of steam bottled up in the reheat circuit of reheat turbines were the subject of three papers. Reheat units built in the 1920's were designed with a single line of defense against overspeed (which had a potential of around 25 per cent). Units shipped in 1949 and 1950 had overspeeds of about 30 per cent and ratings such that no serious damage was expected upon failure of an intercept valve following a loss of full load. But this picture changed rapidly, as **M. A. Eggenberger** of the General Electric Co. pointed out, for nearly a third of the units shipped from 1952 on had as much as 40 per cent potential overspeed, and some of them were as high as 55 per cent. These higher speeds are definitely unsafe.

For primary steam flow it is the universally accepted practice to provide two lines of defense in the form of control valves operated by the speed governor and stop valves operated by the emergency governor. For reheat steam flow the need for a second means of protection is not so clear cut until potential overspeeds of current units are taken into consideration. For a time power-operated relief valves were considered as a second line of defense but were rejected because of such problems as insuring regular testing and maintaining tight seating and the possibility of overloading the last high-pressure turbine stage during an accidental opening.

Mr. Eggenberger concluded that reheat stop valves in series with intercept valves provided the best solution. Stop valves are capable of limiting overspeed to about 16 per cent, do not require tight seating, and permit the designing of a fail-safe control system without compromise.

A second paper in this series was presented by **Edwin G. Noyes, Jr.,** of Westinghouse Electric Corp. who presented methods for potential overspeed calculations. He analyzed the factors by which entrapped steam and evaporation of condensate would lead to overspeed. Regardless of the degree of protection provided, the dependability of the equipment to function in an emergency is determined to a large extent by the user's maintenance program and regular testing of the protective devices. The paper presented data suitable for the designer to evaluate potential overspeed due to 1000 lb of steam entrapped in the reheater and associated piping and

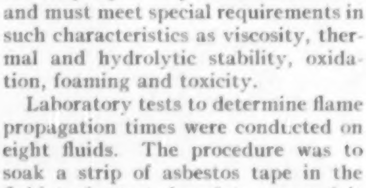
due to the storage of 100,000 lb of water at saturated temperature in the deaerating heater.

C. L. Ringle of Allis-Chalmers Mfg. Co. stated that a typical 150,000-kw cross-compound reheat unit possesses rotational kinetic energy equivalent to 1,340,000 Btu, and that the reheat system is capable of storing steam having an energy potential of 600,000 Btu. Using a typical size reheat turbine as an example, he discussed and evaluated the relative merits of different methods of overspeed protection. The weight of evidence should favor the reheat stop valve installed in series with intercept valves. Apart from its economic advantage, the reheat stop valve makes consistent logic in the form of protection for both primary steam and reheat lines. If only a single line of defense is favored, the relative merits of a pair of intercepting valves versus a pair of dump valves indicate about the same degree of protection, assuming good operational condition of the valves and controls. However, Mr. Ringle, as did the other speakers, strongly urged that the policy of employing two lines of defense against reheat overspeed by adopted.

Turbine Lubricants

Two engineers from the large steam turbine department of the General Electric Co., **Dr. G. V. Browning** and **Peter G. Ipsen,** presented a paper entitled "Evaluation of Nonflammable Fluids as Steam-Turbine Lubricants." They described the characteristics necessary for the fluid used to lubricate turbine bearings and to operate control mechanisms. In addition to nonflammability the fluid must possess lubricity equal to present turbine oils and must meet special requirements in such characteristics as viscosity, thermal and hydrolytic stability, oxidation, foaming and toxicity.

Laboratory tests to determine flame propagation times were conducted on eight fluids. The procedure was to soak a strip of asbestos tape in the fluid to be tested and to suspend it vertically from a bar so that the lower end contacted a small hot natural



Asbestos strip flammability test

gas-oxygen flame. Flame propagation times ranged from 5 seconds for hexachlorobutadiene to 40 seconds for silicone oil.

Oxidation stability tests were carried out in accordance with ASTM procedures. These tests were in the nature of a preliminary survey and served as a basis for setting up proposed specifications for nonflammable turbine lubricants. Although none of the liquids tested is suitable in its present form, it is hoped that chemical manufacturers will be able to modify existing fluids or develop new ones for this exacting service.

Packaged Steam Generators

"Design and Operation of Fully Automatic Shop-Assembled Boilers" by **E. A. Kazmierski** of The Babcock & Wilcox Co. was the first paper in a symposium on this subject. The author reported that approximately 500 boilers of this design had been placed in service since 1949. He described the development of safety equipment, including interlocks and the normal cycle of operation for oil firing. Positioning-type electrical or pneumatic combustion control and metering-type pneumatic combustion control may be installed in this boiler.

A. W. Hindenlang of Combustion Engineering, Inc., in a paper entitled "Selection of Control Equipment for Packaged Watertube Steam Generators," dwelt mainly with the philosophy of control selection and the extent to which fully automatic operation can be justified. One of the first decisions to be made is whether the firing cycle, including flame-safeguard control, is to be fully or semiautomatic. Then the number of limiting controls must be decided upon, evaluating the relative possibilities of dangerous operating conditions and the nuisance values of shutdowns caused by faulty control functioning. Finally, a decision must be made as to whether the combustion control system should be of the positioning or metering type. Almost all steam-generator manufacturers are in a position to offer integrated systems composed of the three preceding fundamental components.

For the third paper, **E. J. Lachner** of Foster Wheeler Corp. had as his topic "The Application of Automatically Controlled Watertube Packaged Steam Generators." He pointed out that the economic aspects of selecting these units are not as well understood as the physical considerations, for substantial differences exist in efficiency and quality of construction. Another factor that needs clarification is control selection, since it is common to encounter specifications that are unnecessarily elaborate with

respect to instruments and controls. Oftentimes the equipment specified is neither required nor advantageous for this type of plant, and the equivalent cost might be advantageously applied to increasing steam capacity or supplying a more efficient unit. Standard safety devices should never be omitted, but controls should be kept as simple as possible.

In a paper entitled "Recent Developments in Packaged Firetube Boilers," **F. A. Loebel** of Cleaver-Brooks Co. traced the history of this type unit over the past 20 years. Construction was originally of the all-riveted type because of a lack of ASME Boiler Code provisions for all-welded firetube boiler, but since 1949 the latter procedure has been approved and adopted as standard. Improvements made in recent years include (1) greater reliability of safety controls, (2) more conservative furnace and heating surface without sacrifice in compactness, (3) automatic burners for natural gas and residual fuels, (4) lower noise levels, (5) improved accessibility for maintenance, and (6) improved manufacturing techniques.

Discussion

Mention was made of the desirability of improving forced-draft fans for packaged boilers, particularly to reduce noise level. Because of the compactness of these units there has been a tendency to locate them in areas with limited accessibility.

Accessibility to controls was discussed, and one engineer was of the opinion that it was best to lock them up to prevent tampering except at scheduled maintenance periods. Much higher heat releases in packaged boilers were forecast on the basis of experience gained in marine boilers and gas-turbine combustors.

Supercritical Pressure Cycles

Prof. Jerome Bartels of the Polytechnic Institute of Brooklyn and Gibbs & Hill, Inc., re-presented his paper entitled "Thermodynamics of Supercritical Pressure Steam Power Plants." In an appendix based upon the microscopic approach to understanding physical phenomena in the monophase region above critical pressure, he offered the following explanation:

"Evaporation consists of a surface molecule in a liquid cluster acquiring adequate thermal energy to overcome the potential binding forces of its neighbors and to break away clear of the cluster. The binding forces between the surface molecule and molecules well below the surface need not be considered, only the adjacent neighbors, for potential forces drop off extremely rapidly with increasing

distance. High pressures require higher thermal energy, and therefore higher temperature, for the surface molecule to break free of the cluster. At supercritical pressures, the potential forces no longer can be overcome by the thermal energy, and no molecules escape free of the clusters. However, as the supercritical pressure fluid undergoes a temperature rise, the average size of its clusters diminishes. At still higher temperatures, the clusters are reduced down to isolated molecules, and all traces of crystalline structure have disappeared. Thus, the supercritical pressure fluid acquires its steam-like qualities not by evaporation of isolated surface molecules, but rather by the gradual diminution in the size of the clusters."

Heat Transfer

C. M. Simmang of Texas A. & M. College, **F. T. Saadeh** of Minneapolis-Honeywell Regulator Co. and **B. E. Short** of the University of Texas presented an analytical study entitled "Heat Transfer in the Rotating-Element Air Preheater." They found that the heat-transfer coefficients in this type heat exchanger do not differ appreciably from the stationary-surface type. The speed of rotation lessens the time of contact of the plates with the fluid and affects the plate temperature change but has no effect on the total heat transferred within the speed range of the experiments. Also it was found that the plate thickness has no effect on the total heat transferred for the same terminal temperatures and fluid velocities.

In one of a series of three papers under the general title of "Heat Transfer Rates for Crossflow of Water Through a Tube Bank at Reynolds Numbers up to a Million," **O. E. Dwyer, F. L. Horn** and **Joel Weisman** of Brookhaven National Laboratory presented forced-convection boiling and pressure-drop data. Contained in the report were the effects of pressure, heat flux and flow rates on the inception of nucleate boiling, including their effect on heat-transfer rate under boiling conditions and in the transition stage between nonboiling and full surface boiling.

Gas Turbine Testing

A total of three papers were given on the general subject of gas turbine testing. These are abstracted on page 76 of this issue. In the main they covered the extent of testing requirements necessary to gain adequate data on the performance of gas turbines so that the information would be reproducible and, hence valuable as reference for further programs.

New Books

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N.Y.

Elevated-Temperature Properties of Chromium-Molybdenum Steels

This is the second in a current series of reports prepared under the auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals. The report, which was prepared by W. F. Simmons, and H. C. Cross, is a graphical summary of strength data for these steels. It includes curves for tensile strength; 0.2 per cent offset yield strength; per cent elongation and reductions of area; stresses for rupture from 100 to 100,000 hr in multiples of ten; stresses for creep rates of one per cent in 10,000 and 100,000 hr and Larson-Miller master curves.

Primary data from which the summary curves have been prepared are included in the Appendix. The data sheets include the chemical composition, processing data, heat treatment and other pertinent information about the steels covered in the survey. Among the compositions covered with charts and tables are:

$^1/_2$ Mo	3 Cr-1 Mo
Ni-Cr-Mo	5 Cr-$^1/_2$ Mo
1 Cr-$^1/_2$ Mo	5 Cr-Mo Ti
1 Cr-Mo V	5 Cr-Mo Si
1$^3/_4$ Cr-$^1/_2$ Mo	7 Cr-$^1/_2$ Mo
2 Cr-$^1/_2$ Mo	9 Cr-1 Mo
2$^1/_4$ Cr-1 Mo	

The paper-bound report contains 200 figures, including summary curves for 23 steels, and more than 250 data sheets for 52 steels. Price of the 212-page report is \$4.75.

Flow and Fan

By C. Harold Berry

The underlying purpose of this book is to serve the user who must select a fan to meet specific needs. It is intended primarily for those interested in ventilation practice. The author has attempted to present a simple statement of the data needed and the methods used for finding the aggregate resistance of a system. Little attention is paid to the theory of fan design.

In the opening chapter underlying assumptions and factors in the measurement of gas flow are discussed. Detailed instructions are next provided for pressure and loss calculations. Three chapters are devoted to losses in straight ducts, diverging passages, and under

special conditions. Subsequent chapters take up fan performance and variables which influence it, a comparison of relationships for the fan and the system, fan selection and rating, and fan operation and control.

There is considerable material on the subject of control of air volume which is of direct interest to power field men. The different means by which control is established—damper, variable speed for drive, vane control, or a combination of them—are discussed in quite some detail and a number of supporting curves of fan performance and volume are keyed to the material.

There are 226 pages in the book which sells for $4.00.

Bibliography of Natural Gas

By Richard C. Henshaw, Jr.

This is another in a series of selected and annotated bibliographies prepared by the Bureau of Business Research of The University of Texas. It lists sources which were studied and reviewed in preparation for the book, "Economics of Natural Gas in Texas," which Mr. Henshaw co-authored with John R. Stockton and Richard W. Graves. The present work includes all references compiled during the writing of the book and in addition includes some items published since 1952. The following topics are covered: economics of natural gas, natural gas liquids, petrochemicals, research, transportation and storage, public control, conservation and competitive fuels.

The 61-page paper-bound pamphlet sells for $1.50.

Lubrication of Industrial and Marine Machinery

By the late W. G. Forbes
Revised by C. L. Pope and W. T. Everitt

In this book a new interpretation of the material of lubrication is presented in the light of modern developments. It includes graphic descriptions of the characteristics of conventional lubricants and a detailed analysis of the chemistry, refining, compounding and specifications of lubricants. Basic mechanisms are studied in their relation to lubricants, and the authors dwell at some length on the limitations to which lubricants can be put.

Among the subjects covered are the chemistry of petroleum, refining light distillates and lubricating oils, fatty oils, methods of testing lubricants, bearing lubrication, applications to various types of machinery and prime movers, heat-treating oils and cutting oils.

There are 351 pages in the book which sells for $6.50.

NEW CATALOGS AND BULLETINS

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Demineralizers

A highly practical review of demineralizers makes up the subject matter of the 22-page Bulletin WC-111 put out by the Graver Water Conditioning Co. Included are special sections on operating costs of various demineralizing systems, a curve for rapid determination of operating cost, operating cycles, the internal structure of a typical demineralizer tank and the piping and fitting materials needed for a complete hookup.

Valve Operator

A new 4-page bulletin of the Philadelphia Gear Works portrays the company's SMA-00 and Limitorque valve control for the operation of small valves. These units are said to give greater valve stem capacity, more stem torque and prove capable of withstanding greater thrust than other valve controls. The various elements making up the assembly plus their major features are explained and pictured.

Continuous Blowoff

A 12-page bulletin, No. 2391A, released by The Permutit Company, points out the advantages of greater blowoff but at a definitely controlled rate to meet the requirements of higher boiler pressure and higher rates of evaporation. There are four typical arrangements provided in the manufacturer's automatic continuous blowoff equipment to furnish an economy of fuel, a smaller blowoff quantity, a reduced makeup and less strain on boiler metal.

Rotary Compressors

The operation and construction of single-stage, water-cooled rotary compressors and vacuum pumps as manufactured by Allis-Chalmers Mfg. Co. comprise the material in the 12-page bulletin, 16B8126. The bulletin cites eight reasons for lower cost service of these units and furnishes specification along with typical piping diagrams.

Temperature Controls

Bulletin 103 of the Burling Instrument Co., covers the manufacturer's models, B-1C and B-1X, used for controlling temperatures or as high- or low-temperature safety alarms and cutouts up to 1000 F. The units operate by differential expansion of solids; come in weathertight and explosionproof housings. The bulletin explains the operation, gives dimensions and methods of mounting.

Diatomite Filters

Simple, economical and efficient filtration of raw water supplies is covered in the Bulletin WC-115, a 4-page release by the Graver Water Conditioning Co., devoted to the company's diatomite filters. Text, photographs and schematic diagrams depict the operation of these units and their advantages.

Turbidity Measurements

Data Sheet No. 10.14–5 available from the Industrial Div. of Minneapolis-Honeywell Regulator Co. explains the applications and working of the continuous indicating and recording devices for turbidity measurements. The particular device described combines the manufacturer's Electronik potentiometers with a recently developed General Electric Co. turbidimeter.

Welding Tees

A new 4-page booklet, entitled Brawny, published by the Northern Indiana Brass Co., introduces a new line of carbon steel welding tees and gives advantages, list prices and complete dimensional and weight information.

Power Transmission

A special fold-out bulletin, No. 6638, available from the Manhattan Rubber Div. of Raybestos-Manhattan, Inc. pictures the newly developed poly-V drive that is said to combine the simplicity and strength of flat belts with the speed and grip of V-belts. The major advantages are easy matching, greater power capacity, constant effective pitch diameters at all loads and considerably less space needs.

Motorpumps

In a 16-page booklet, Form 7123, Ingersoll-Rand Co. has put together a slidefilm in booklet form that pictures

vital selection information, performance factors for consideration, plus the workings and description of a centrifugal pump. A typical problem and its solution based on the slidefilm information follows to make the booklet a practical aid.

Mechanical Drive Turbines

The velocity stage, Class CA mechanical drive steam turbine, manufactured by De Laval Steam Turbine Co. features a new 4-page bulletin No. 4202 now available. This design operates under all inlet steam conditions up to 600 psig and 750 F and with modified construction, up to 825 F. A large cutaway drawing pictures the design features and together with a full page of specifications the CA is fully described.

Blowdown Control

Technical Paper No. 238 prepared by W. H. & L. D. Betz discusses the principal types of boiler blowdown as well as the various control methods to assure pure steam and clean surfaces.

Steam Trap

The V. D. Anderson Co.'s 36-page catalog, "Solving Steam Trap Problems," has been brought up to date to include information on the company's new combination float and thermostatic traps. In addition the revised catalog contains specifications and capacities on steam traps, float traps, air release valves and pipe line strainers. Condensation loads are calculated and help given in selection of traps for all classes of equipment.

General Purpose Turbines

The complete line of Westinghouse Electric Corp. Type E turbines in ratings through 1500-hp appear in the 20-page booklet, B 38-96. Design and constructional features as well as those of accessories are included and their application to a score of equipment such as coal pulverizers, fans, pumps, compressors and generators are given.

Control Equipment

A greatly revised edition, Bulletin 004, of a 1950 general catalog of Simplex Valve & Meter Co. lists in 36 pages all the manufacturer's equipment for the measurement and control of liquids and gases. Many types of gages, manometers, recorders, meters, Venturi tubes, valves are shown.

Material Handling

Bulletin No. 400, a 32-page release of Gifford Wood Co., describes and illustrates specific industrial examples

of the company's material handling system of an industrial plant. Technical information is supplied on conveyors, elevators, and feeders, plus dusttight gates and screw feeders.

Steam Instrumentation

A convenient, one-source reference for all products of the Industrial Div., Minneapolis-Honeywell Regulator Co., can be had in the recently released 28-page Bulletin 9050, entitled Instrumentation for Steam Generation. The bulletin is indexed and broken down into some 26 headings ranging from flow, liquid level, temperature, pressure to pH, valves, flue gas analysis and combustion safeguard systems.

Flowmeters

Catalog 2320, a 56-page Industrial Div., Minneapolis-Honeywell Regulator Co. publication, describes all types of flowmeters made by this manufacturer. It includes indicating, recording, integrating and controlling instruments of both evenly graduated and square root types as well as area meters and differential converters.

Proportioning Pumps

A 6-page bulletin of the Hills-McCanna Co. describing their "K" type metering and proportioning pumps has been made available. The unit, a completely enclosed in-line, direct-acting, hydraulic drive pump with built-in pressure relief valves, is explained and capacity and pressure information furnished.

Centrifugal Pump

The 4-page illustrated Bulletin 1001 B released by DeLaval Steam Turbine Co. covers their type GS centrifugal pump which can be ordered from stock with all parts interchangeable and standardized. The ease of maintenance and service are featured in the bulletin.

Induction Motors

Reliance Electric and Engineering Co. have released a 12-page bulletin, B-2102, as an aid in selecting squirrel cage induction motors, both their new line and current line, for applications ranging from 1- to 200-hp. Performance characteristics, construction features, dimensions and other data are supplied.

Gaskets

A complete catalog, Bulletin No. AG-953, has been put out by the United States Gasket Co. in their Ajax spiral wound gaskets for pipe flanges, boiler manholes, handholes

and tube caps, water walls and economizers. Easy reference flange gasket and boiler gasket dimension tables and bolting data are included.

Filming Amines

Technical Paper No. 217 of the W. H. & L. D. Betz Co. is a 4-page reprint of an article entitled "Experiences with Filming Amines in Control of Condensate Line Corrosion." The chief culprit for condensate line corrosion is identified as carbon dioxide in steam and water and the role of filming amines in combatting it is discussed.

Graphitization

A 12-page booklet entitled Graphitization is a reprint of an article by W. L. Hemingway, research metallurgist of Edward Valves, Inc. on the phenomenon of carbon migration in the heat affected zone of welded piping in high temperature service. It discusses graphitization from the standpoint of temperature, chemical composition, deoxidation practice, and prewelding microstructures.

Turbine Speed Control

Bulletin H-21, a 30-page Elliott Co. release, is an illustrated, educational publication that is intended to clarify the operation of common types of automatic speed control for steam turbines. The general fundamentals are covered in an introductory section. Simplified diagrams illustrate operating principles of actual controls.

Mixed Bed Demineralizers

The advantages of bed demineralization are detailed in an 8-page bulletin, No. 3983, of Permutit Co. This release is made up from a paper "Automatic Mixed-Bed Demineralizing at the Albany Steam Plant." A table compares the equipment cost of an evaporator plant with a demineralizer and indicates the capital expenditure savings.

Level Controls

A new 24-page catalog, SC-5, of McDonnell & Miller, Inc., is a revised edition of an earlier catalog and contains fairly complete engineering information, capacity curves and roughing-in dimensions for the manufacturer's boiler feeders, low water cutoffs, pump controllers and relief valves. Many of the special adaptations and components that have been developed of recent years are featured.

Oil Burners

A fold-out bulletin, AD-131, put out by Cleaver-Brooks Co. features their new "4" Hev-E-Oil Burner. Its com-

pactness, simplicity of design and many other engineering features are explained and portrayed.

High-Temperature Water

A special 6-page leaflet "Use High-Temperature Water Now to Step Up Efficiency, Produce More Power" is a reprint by the American Hydrotherm Corp., of a paper that shows high temperature water (250 to 400 F) as an economical heat carrier for heat recovery and heat distribution as well as a tool for regenerative heating in power plant cycles.

Mechanical Drive Turbines

The 16-page Elliott Co. bulletin, No. H-22, gives emphasis by large, detailed illustrations to design features, and proper control of this type YR mechanical drive turbine. Modifications, specifications and dimensions are detailed.

Heavy-Duty Compressors

The Joy Mfg. Co., series 100, Class WN-114 heavy-duty air compressors for industry are discussed in a recent 36-page bulletin, A-72, which gives complete information on construction and operation of the compressor. Seven models are shown for a single unit and others are pictured in operation as twin units.

Panel Instruments

The General Electric Co. line of panel instruments are carried in the 12-page bulletin, GEC-368F, which describes the various equipment listed, covers construction and supplies ac and dc instruments.

Water Gages

The recently developed 12 major improvements in Yarway flat-glass high-pressure water gages are described in a completely new 20-page catalog, WG-1814, released by Yarnall-Waring Co. In addition it describes the round-glass gages for pressures up to 400 psi plus the flat-glass features of separate design, floating assemblies and inserts and type M illuminators for pressures up to 2500 psi.

Seatless Piston Valves

A 4-page bulletin entitled Seatless Piston Valves has just been made available by the Klinger Corp. of America. Details are provided on the different valve body types, namely, cast bronze, forged steel and cast steel. Weights and dimensions are furnished and some of the operating features explained.

Centrifugal Pumps

An educational 12-page booklet, Form 7287, available from Ingersoll-Rand Co., presents in simple language with ample illustrations the principles of operation, the various terms used in pump calculations and some sample problems.

Aluminum Heat Exchangers

The complete story on aluminum heat exchange tubes is covered in a 24-page booklet of that name released by the Aluminum Company of America. Service and laboratory experience are given as well as the economics in aluminum tube selection, the types available and the corrosion protection advantages. A section has been furnished on general design data, alloy recommendations, and fabrication plus tables and discussions on heat transfer, fluid flow, estimating data and characteristics.

Hose Coupling

A 16-page booklet of the Titeflex Quick-Seal Coupling, describes the simple construction of the company's coupling for hose lines carrying oil as well as other fluids and gases. The bulletin features a sealing action which is said to prevent leakage and yet permit a full swiveling action that avoids hose twists and kinks.

Motor Starters

Short circuit protection for 2200–5000 volt systems is part and parcel of the motor starters in the Electric Controller & Mfg. Co. booklet 1062.

Plug Valves

A new 24-page reference book, No. 39-5, shows the Homestead Valve Mfg. Co. lubricated plug valves in full-port and venturi types, sizes up to 14-in. and with a choice of self-sealed, two-piece plug or one-piece plug designs. Principal dimensions, control types, metals and lubricants are shown.

NEW EQUIPMENT

Volt-Ammeter

New hook-on volt-ammeter, the AK-5, believed to be the first with automatic scale changing, has been developed by the General Electric Co.'s meter and instrument department. It is pocket-size and designed to measure current and voltage

quickly and accurately. There are four ampere ranges, 5/20/80/350 amperes, and three ac voltage ranges, 150/300/750 volts, without auxiliary equipment. Measurements are within 3 per cent accuracy. The desired range and scale is obtained by turning the unit's switch knob.

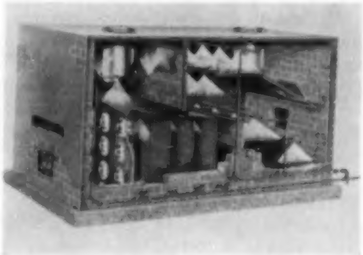
High Pressure Valves

Newest addition to high pressure control valve line manufactured by the Annin Co., 6570 E. Telegraph Rd., Los Angeles 22, Calif., is the series 34 valves for pressures up to 6,000 psi and temperatures up to 900

F. Models are available for motor operation cylinder or manual. Valves come in sizes $^1/_2$-in. and $^3/_4$-in. in a wide selection of body and trim materials in both offset globe and angle bodies.

Gas Scrubber

Liquid precipitating stack gas scrubber developed by Johnson-March Corp., Philadelphia, Pa., for installation in low-cost housings of cinder block, concrete or fabricated steel



comes in eight models that can handle high temperature gases in capacities ranging from 8000 cfm to 60,000 cfm. About $2^1/_2$ gal. of water per minute at 40 to 50 psi are needed per 1000 cfm. The equipment is particularly suited for stack dust from kilns, roasters, mixers, sintering plants and similar industrial installations.

Emergency Light

Automatic standby, emergency light, Model 116, supplied by the Carpenter Mfg. Co., Boston 45, Mass. conforms to the latest National Fire Code and is fully UC approved. The glass jar (non-automotive type) battery can deliver 91 per cent of rated

capacity after thirty minutes of actual use. There are external switches for quick testing and other switches to control the battery charger and disconnect lampheads if the unit is out of service. Visible disk-float hydrometer eliminates any need for ladder climbing.

Instrument Air Drier

A small desiccant air and gas dehydrator designed especially for isolated pneumatic equipment has recently been developed by Hankinson Corp., 146 Biltmore Bldg., 951 Banksville Rd., Pittsburgh 16, Pa. Rated at 1 scfm at 100 psig and 70 F the Dehydrafilter features a disposable desiccant cartridge and "O" ring seal construction that eliminates any tools to remove or change the cartridge.

Strainer Trap

A large model integral steam trap, No. 882, has been added to the line of Armstrong Machine Works, Three Rivers, Mich. It is said to cost less than a standard trap plus separate Y-strainers and require less fittings to install. The stainless steel strainer

screen sets in the body casting at the bottom of the trap. Internal parts of the trap itself are chrome steel and stainless. Model 882 has horizontal and opposite pipe connections of $^1/_2$- or $^3/_4$-in. size with capacity ranges from 1300 to 2200 lb per hr.

Excitation System

An inductor alternator substituting for the usual dc machine gives an en-

tirely new exciter system for (1) modernization of older generators or for (2) inclusion with new units, according to Allis Chalmers Mfg. Co., Milwaukee 1, Wis. The heart of the system is the 360-cycle inductor generator which has no windings, commutator or slip rings. Power for

excitation is generated at high frequency and then changed to dc by a bank of selenium rectifiers. The rotating element of the ac exciter is adaptable to overhung mounting on most 3600 rpm generators thereby eliminating case couplings, gears and exciter bearings.

Liquid Level

Closed tank liquid level measurements, either under a pressure or a vacuum, can be performed with a differential converter, just announced by the Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrin Aves., Philadelphia 44, Pa. The instrument uses a pneumatic balance, weigh-beam system readily adjustable in the field for applications from 0–14 to 0–200 in. of water.

Centrifugal Blower

Large volume, standard production centrifugal blower developed by the Air Applicance Div., U. S. Hoffman Machinery Corp., 105 Fourth Ave., New York, N. Y., employs three interchangeable impellers that permit a factory assembly to give any air volume between 2000 and 9000 cfm with pressures ranging from 1 psig to 9 psig or vacuum from 2 to 12-in. Hg.

Packaged Compressor

The PHE, an opposed-cylinder, balanced-design, two-stage, packaged air compressor in the 75–100 hp range has recently been announced by the Ingersoll-Rand Co., Phillipsburg, N. J. This unit is said to approach the efficiency of larger, slow speed designs for air pressures in the range of 80–125 psi. It is driven by a direct-connected induction motor, requires very little floor space, a simple foundation and a minimum of piping and connections.

Gas Turbine Test Results at ASME Meeting

At the recent Fall Meeting of the ASME reported in detail on page 63 three reports were given on gas turbine testing procedurs and results. These are briefed in the space below.

T. D. McKone and **R. L. Hendrickson** of the General Electric Co. explained the methods and described the facilities in which their company conducted tests of 93 commercial gas turbines manufactured during the period 1946 through 1953. They pointed out that the ASME Gas Turbine Power Test Code does not describe a method for correcting test results to contract conditions. In order to predict with reasonable certainty that each plant will be able to exceed performance guarantees, factory test results are corrected to contract conditions by calculation. The authors presented an example to show how such calculations may be carried out and expressed the hope that some such system would be established by the ASME Power Test Codes.

Some idea of the amount of data collected in testing a regenerative-cycle two-shaft gas turbine may be had by knowing that 1273 readings are taken for each load point, of which 380 are pressures and 445, temperatures. About half of these are actually used in performance calculations. As gas turbines increase in size, factory testing may have to be replaced by performance guarantees over wider ranges of operating conditions and the use of approximate corrections to compare with actual installations.

Two comprehensive papers were presented under the title "Acceptance and Operational Tests of a 4250-Hp Coal-Burning Gas Turbine," by **J. I. Yellott, P. R. Broadley** and **W. M. Meyer** of the Locomotive Development Committee of Bituminous Coal Research, Inc. The first paper discussed preliminary oil-fired operation of an Allis-Chalmers gas turbine installed at Dunkirk, N. Y. The official acceptance test was run on September 28, 1951, at which time the calculated shaft horsepower was 4257 at rated conditions, or 13.5 per cent above that guaranteed. Based on test data the cycle efficiency was 20.17 per cent.

In the second paper the authors described the coal handling system, combustion and ash-separation methods. They gave the results of a 168-hr period of preliminary coal-burning operation, using oil pilot flames in the combustors. Blade erosion was negligible and ash deposits were completely absent. The specific fuel rate for a 750-hr test was 1.03 lb per hp-hr.

Con Edison Erects Special Coal-Handling Dock

A steel coal-dock that is basically a coal barge will handle coal deliveries at the Consolidated Edison Co. of New York's new Astoria generating station. The barge, photo below, has been pierced by numerous cylindrical steel sleeves. Then steel cylinders six feet in diameter were lowered through these sleeves until they reached bottom. By means of special, double-action jacks working on each cylinder the barge was made to "climb" up on the cylinders. The cylinders in the final assembly, become the piles of the finished dock.

DeLong Engineering and Construction Co. was awarded the contract for this form of dock construction after competitive bidding in which the costs of the DeLong dock had to compete with those of standard concrete dock design. DeLong and Con Edison engineers worked out the details of this application with the cooperation and active assistance of New York City's Department of Marine and Aviation.

Con Edison's new dock was built in two sections at Wilmington, Del., and towed into New York Harbor with the steel caissons aboard, a section at a time. The unit erected by mid-September represents the first half of the job.

The DeLong dock was developed as a practical method of quickly providing a dock in a remote and difficult location. During World War II a four-section dock was built in Texan shipyards, towed to and erected in Thule, Greenland, as a part of Operation Blue Jay. A similar dock is in use on the Orinoco River in Venezuela, and a third has been put in place in Alaska. The Con Edison unit in New York Harbor makes the fourth.

In construction, the dock is similar to the radar warning platforms which the Air Force recently announced for off-shore stations on the continental shelf.

Coal will be carried from the dock by a system of conveyors to the two existing boilers of the Astoria Station. Each boiler is rated at 1,200,000 pounds of steam an hour when on coal. Coal handling facilities at the station are designed to be capable of expansion to meet the requirements of four more units at the site.

National Power Show Set for Philadelphia

The 21st National Exposition of Power and Mechanical Engineering is being held in Philadelphia at the Commercial Museum for the first time in its history, December 2, 3 and 4 and also December 6, 7. Admission will be by invitation and registration with no admission fee. An expected 250 exhibitors will feature their equipment.

Two sections of steel barges like the one above, when set on steel piling, will form a 60-ft. wide, 480-ft long coal dock for Con Edison of N.Y. at their Astoria plant

BOOKS

1—Theory and Design of Steam and Gas Turbines

By John F. Lee

502 pages Price $9.00

There is a pedagogical need for a text in which the fundamental theory of steam and gas turbines is presented in a unified form in a single book. It is the intention of the author, who is Associate Professor of Mechanical Engineering at North Carolina State College, to fulfill this requirement.

Following a presentation of basic steam and gas-turbine types, the author has included a concise review of thermodynamics. Steam and gas-turbine cycles are then taken up, after which chapters are devoted to gas dynamics, nozzle design and energy interchanges in fluid machinery. Common aspects of steam and gas-turbine design are discussed in chapters on flow passages and mechanical problems. Consideration of the steam turbine is completed with a chapter on its control and performance. The remainder of the text is concerned with centrifugal and axial-flow compressors, problems of combustion, the regenerator and the gas-turbine power plant.

2—Textbook of the Materials of Engineering

By Herbert F. Moore and Mark B. Moore

372 pages Price $6.00

Now in its eighth edition, this text provides a broad survey of the field of engineering materials. When the first edition was published in 1917, its objective was to furnish a concise presentation of the physical properties of the common materials used in structures and machines, together with brief descriptions of their manufacture and fabrication. Over the intervening years, this objective has been maintained, so that the present edition includes consideration of many materials and techniques which were unknown at the time of initial publication.

The coverage of the properties of materials includes methods of production and chemical and mechanical methods of strengthening materials. Among the introductory chapters are considerations of elastic strength, failure by creep and fracture, allowable working stress and physical properties of typical structural metals. Later chapters are concerned with such materials as wood, building stone and ceramics, concrete, plastics, rubber, leather and rope. A particularly interesting chapter takes up materials specifications writing and the activities of the American Society for Testing Materials.

3—The Elements of Nuclear Reactor Theory

By Samuel Glasstone and M. C. Edlund

416 pages Price $4.80

Based on the course in nuclear reactor theory given at Oak Ridge School of Reactor Technology, this fundamental text has been prepared under the auspices of the Atomic Energy Commission in order to provide essential information for engineers and scientists who plan to prepare themselves to work with reactors for producing power and for other purposes.

Four introductory chapters entitled Nuclear Structure and Stability, Nuclear Reactions, Production and Reactions of Neutrons and the Fission Process have been provided. A thorough understanding and mastery of their content is essential if the meaning of the remainder of the book is to be grasped. At this point it should be made clear that the average mechanical engineer is unlikely to have studied many of the concepts of modern physics covered in these introductory chapters. The reading of this book could be made more meaningful by a parallel study of texts on nuclear physics (at an intermediate level) and on advanced mathematics, including differential equations and vector analysis.

Subsequent chapters take up the diffusion and slowing down of neutrons, homogeneous and heterogeneous reactors, reactor control, perturbation theory and transport theory. Material included in these chapters is devoted to the fundamental principles involved in the calculation of the critical conditions for thermal neutron chain-reacting systems. The main section does have the advantage of being the most complete exposition to date of reactor theory from a single unified point of view.

4—Energy in the Future

By Palmer Putnam

556 pages Price $12.75

This book embodies the results of a study by the author, under contract with the U. S. Atomic Energy Commission, with reference to the probable demands for energy during the next fifty to one hundred years and the ability of nuclear and non-nuclear fuels to meet these demands with reasonable economy.

The study goes into the question of how much longer we can live off capital energy and takes a look at recoverable reserves of coal, oil, gas, oil shale and tar sands, finally examining the likely rôle of nuclear fuels in supplying low-cost energy.

An extensive bibliography of over 50 pages lists the sources of information consulted as well as the names of some 125 specialists who either contributed information directly or by way of reviewing the text in its initial form.

The book is the most exhaustive of its kind that has been undertaken. It represents a long-range view that many will find both fascinating and very valuable as a reference, and particularly as a basis for economic studies. It is most timely at present when energy demands are increasing at a rate that demands re-examination of our fuel resources, and when we appear to be on the threshold of nuclear power application.

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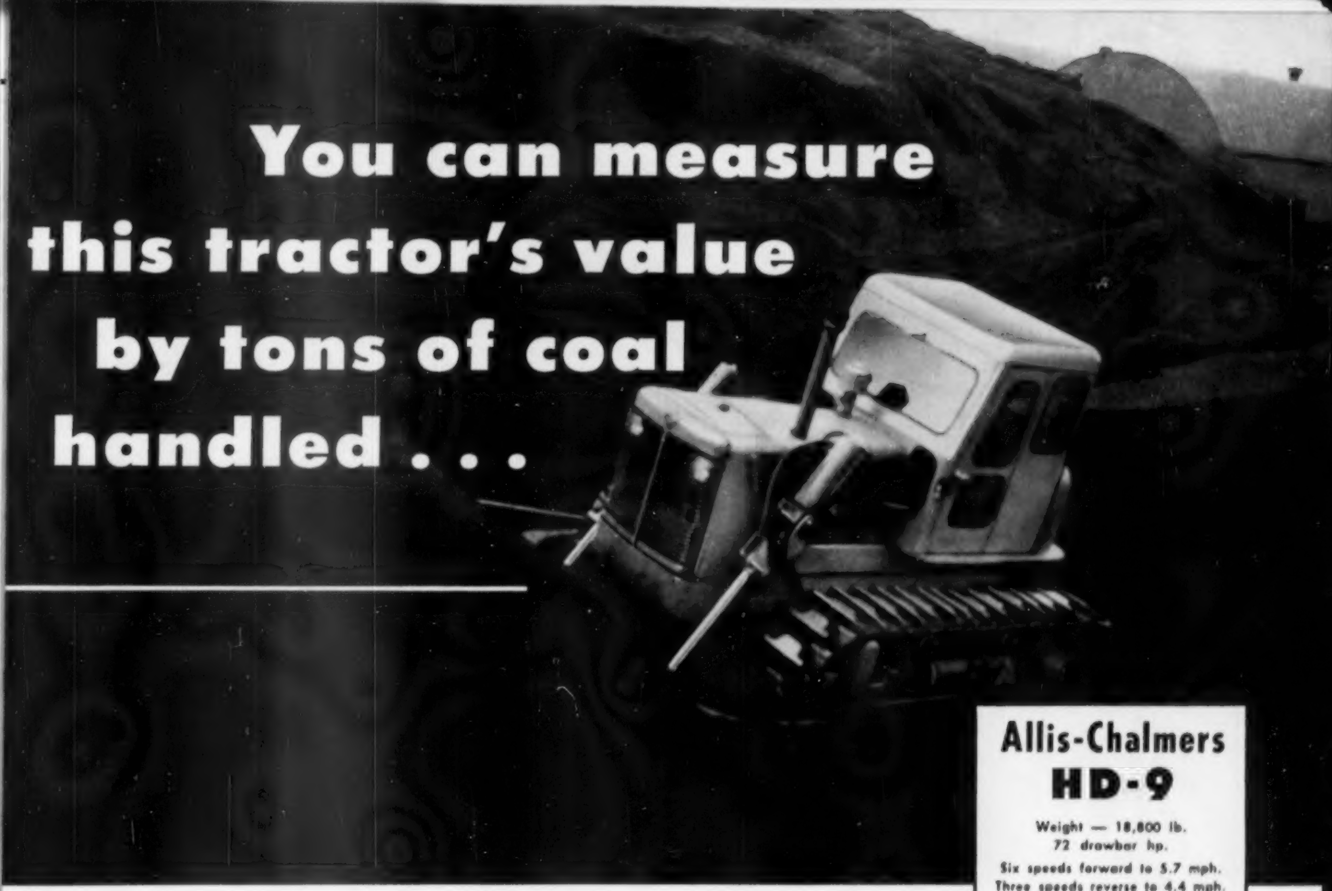
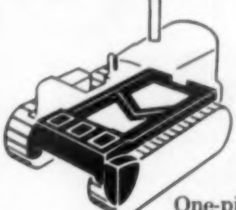


The Allis-Chalmers HD-9 Tractor offers performance reliability and ease of servicing that pays off in year-after-year efficiency on coal handling. Here's what we mean:



Built to stand the gaff of daily use for years . . .

One-piece, welded main frame forms a continuous, strong backbone that means longer life for each tractor.

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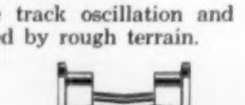
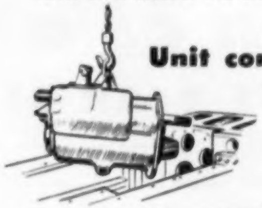


Easier lubrication saves time, helps protect equipment

Lubrication for 1,000 hours for final drives, truck wheels, idlers and support rollers saves both grease and time.

Spring-loaded, positive seals keep grease in, keep dust and water out.

Fewer, more accessible lubrication points make short work of a chore. No lube points at all under tractor.



Unit construction puts tractors back to work sooner

Transmission can be removed as a unit without removing clutch, final drive or bevel gear.

Engine can be removed without disassembling clutch.

Truck frame can be dismantled without removing final drive, sprocket or equalizer spring.

Clutch assembly can be removed without disturbing engine or transmissicn.

Final drive gear and intermediate gear can be removed without disturbing steering clutch.

Each steering clutch can be removed independently without disturbing final drive or bevel gear.

• • •

Let your distributor tell you more about the rugged construction, ease of servicing and outstanding performance ability of the Allis-Chalmers HD-9 Tractor. It's a story that adds up to coal handling dependability *you can measure by the ton.*

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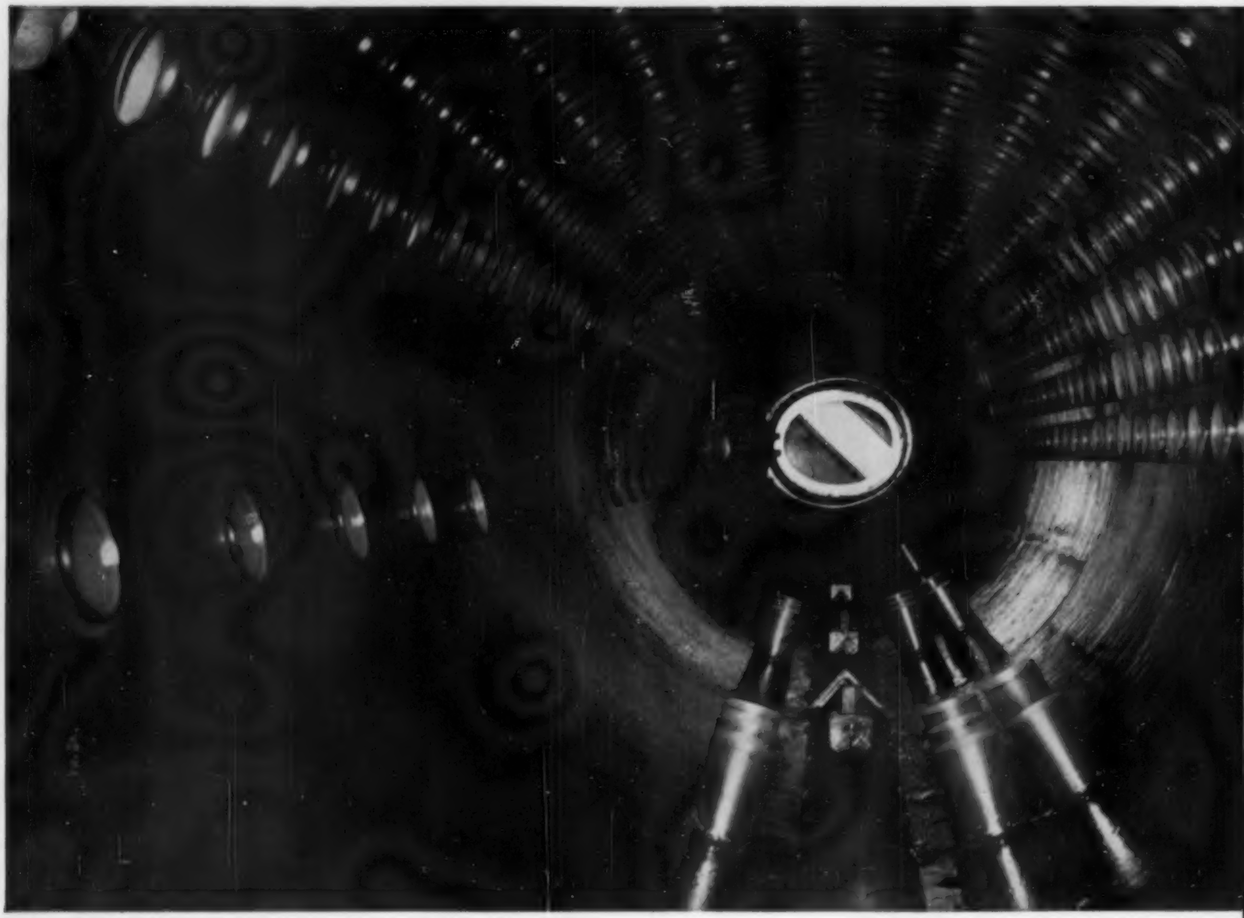

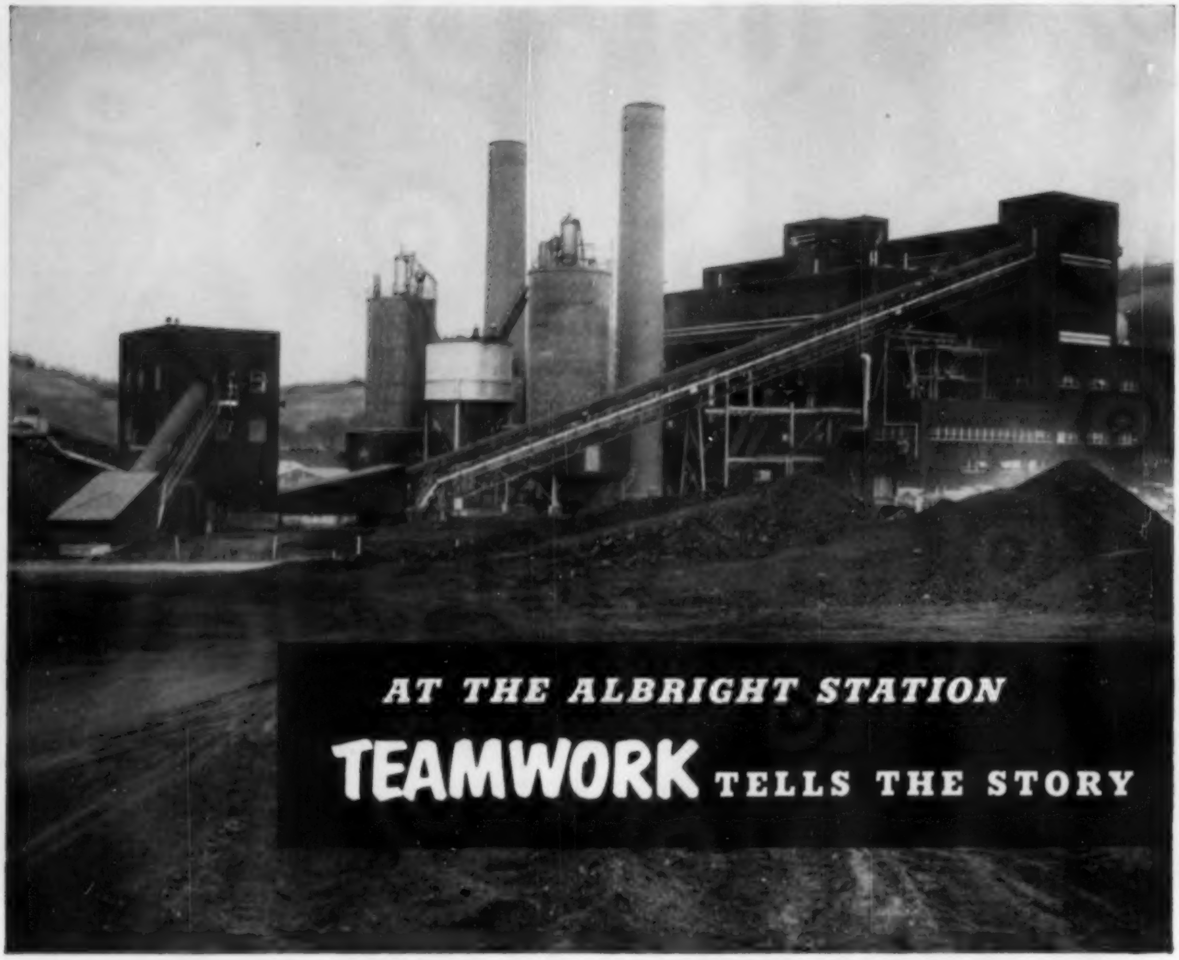

The Albright Station of the Monongahela Power Company and The Potomac Edison Company. Consulting Engineers: Sanderson and Porter, New York City. Net Capability 150,000 KW for the first two units

Yes, TEAMWORK tells the story of the efficient, low-cost coal handling system now in operation at the Albright, West Virginia, Power Station of the Monongahela Power Company, the Potomac Edison Company and West Penn Electric Company. Teamwork, which combined all the experience and "know-how" of the power companies involved...the consulting engineers, Sanderson and Porter...and Chain Belt Company Conveying Engineers.

When you add to the specialized skills of such a team of experts the top efficiency and dependability of Rex Coal Handling Products, you have a combination that will eliminate coal handling "headaches" from your plant for years to come.

Next time you're planning a new coal handling system or expansion or modernization of your present one, put the Chain Belt Conveying experts to work for your team. Just contact your nearest Rex Field Sales Engineer or write to Chain Belt Company, 4784 W. Greenfield Ave., Milwaukee 1, Wis.

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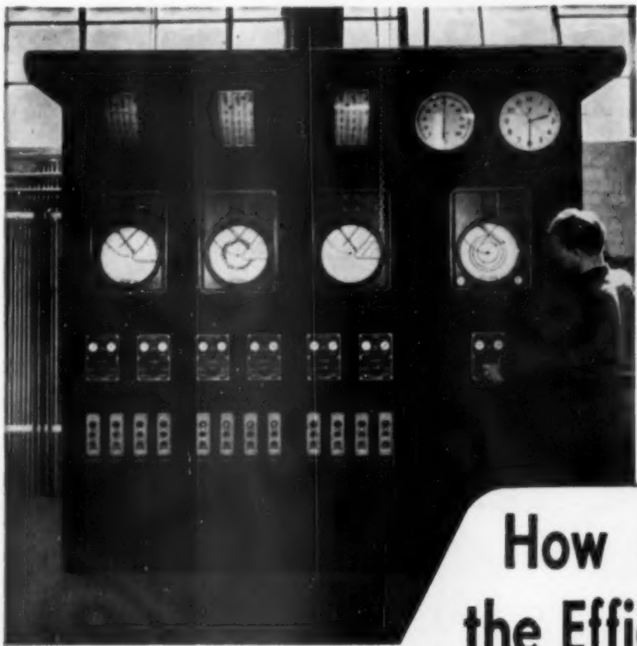

These Bailey Boiler Controls at the Chicago Pneumatic Tool Company's new plant in Utica, N. Y. insure efficient operation of three 25,000 lb per hour, 100 psi, spreader stoker-fired boilers

How to INCREASE the Efficiency of YOUR BOILER-ROOM DOLLAR

Before you get steam you've got to spend dollars—so dollars are a form of energy.

And if your boiler-room dollars are invested in equipment that isn't working efficiently, economically, your "investment" is poor.

That's where co-ordinated controls by Bailey can help. Here's why they'll increase your "boiler-room investment efficiency":

1. **Complete Range of Equipment—fully co-ordinated.** You need never worry that a Bailey Engineer's recommendation is slanted in favor of a particular type of equipment, just because he has a limited line to sell—or that Bailey will pass the buck for efficient control; we offer *complete* boiler control systems.

2. **Engineering Service—backed by experience.** No other manufacturer of instruments and controls can offer as broad an experience, based on successful installations involving all types of combustion, flow measurement and automatic control.

3. **Direct Sales-Service — conveniently located near you.** Bailey Meter Company's sales-service engineers are located in more industrial centers than those of any other manufacturer of boiler control systems; you get prompt, experienced service with a minimum of travel time and expense.

•

For better "boiler-room investment" efficiency—for more power per fuel dollar, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey engineer to arrange a visit to a nearby Bailey installation. We're proud to stand on our record: "More power to you!"

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COMBUSTION · FEED WATER
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Let's face it
...there's more to a bid than price. Some bids are full of gimmicks; some are true. When you receive bids for your specialized piping requirements there's much to consider beyond the price. Your initial saving in accepting the low, low bid that's frequently full of hidden extras is quickly lost in added costs of expediting, in delayed construction schedules, and in correcting faulty fabrication and welding.
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